BIBLIOGRAPHY
of
BIOSATELLITE RESEARCH

Biological Sciences Communication Project
Medical Center
The George Washington University
Washington, D.C.

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The George Washington University
Medical Center
BIOLOGICAL SCIENCES COMMUNICATION PROJECT
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FOREWORD

BIOSATELLITE II was designed as a unique instrument for studying one of the most fundamental and challenging problems of biology—the relationship of gravity to life processes. Years of diligent effort and personally exhausting scientific and engineering teamwork led to the launch of BIOSATELLITE II on 7 September 1967 from Cape Kennedy. Because of certain problems, the originally intended orbital flight of 72 hours had to be terminated prematurely after 45 hours, culminated by successful aerial retrieval on 9 September 1967.

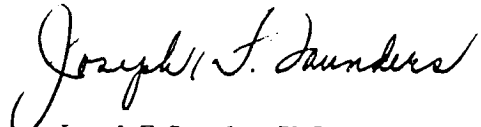
Thirteen experiments, divided into two groups, were flown in this nation's first space biology laboratory to study the effects on life processes of: (1) weightlessness or greatly reduced gravity; and (2) the effects of weightlessness combined with gamma-radiation. The basic goal of the flight was to determine the effects of the space environment on fundamental biochemical processes in cells, the development and growth of plants and animals, the structure of living tissues, and changes, if any, in genetic transmissibility. Specifically, with the radiation-weightlessness experiments, the experimenters were interested in learning whether weightlessness would be synergistic, antagonistic, or unresponsive in its interaction with radiation. In general, the objective of BIOSATELLITE II was to perform experiments to explore the role of gravity in the maintenance of normal organization and function in living systems. A second objective was to obtain information on molecular, genetic, and cellular changes for a better assessment of the possible hazards to living systems of a new spectrum of physiologic stresses encountered during space flight.

The BIOSATELLITE III experiments were performed on a male pigtailed monkey, *Macaca nemestrina*, selected from a large group of monkeys used for baseline experiments as well as flight passenger candidates. The scientific objectives of this mission included the determination of any changes that might be attributed to weightlessness on central nervous system function, performance of the cardiovascular system, general metabolic processes, and alterations in the dynamics of the musculoskeletal system. A variety of space flight factors were observed to determine if perturbations in the circadian or 24-hour cycle were the result of their single or combined action.

This variety of biosatellite experiments covered a panorama of biologic phenomena and made it possible to make a preliminary assessment of the effect of the space environment on biologic function in both plant and animal systems. The scientific success of BIOSATELLITES II and III represents the beginning of a development of understanding of the role of gravity on the function of life on Earth.

One of the remarkable features of the Biosatellite Program was its interdisciplinary character, bringing together a team of scientists, engineers, and managers to accomplish a national space bioscience objective. It is their work which made this bibliography possible and, hopefully, provides a biologic legacy that will stimulate scientific minds for decades.

My gratitude is endless for their contributions and my personal associations with the biosatellite team. I am very grateful, as is the bioscience community, to The George Washington University Biological Sciences Communications Project and, in particular, to Mrs. Jean Pulliam and her staff, for the preparation of this bibliography, which I consider to be a milestone in modern biology.



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CONTENTS

INTRODUCTION

The primary purpose of this bibliography is to bring together in a systematic manner, the publications which have resulted so far from the NASA Biosatellite Program. The publications cited were collected from primary sources, secondary sources (abstracting and indexing journals), and through correspondence with principal investigators and program managers. Final selection and classification of the references was accomplished under the direction of Dr. J.F. Saunders.

Most of the publications cited are available in the open scientific literature, and can be obtained through university and institutional libraries. Copies of some of the "hard-to-get" publications were furnished by the National Library of Medicine, Bethesda, Maryland. Reports and documents, generated by institutions and agencies, that do not appear in the open literature can be obtained from the National Technical Information Service, Springfield, Virginia 22151, or from The Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The distribution of the literature, referenced here, throughout the scientific journals and other publication media is discussed on page 119.

Each bibliographic entry consists of a complete citation (authors, title, and publication source), followed by an abstract. These entries are arranged in alphabetical order according to the last name of the primary author, and chronologically by publication date, under each of four subject headings. An author index, permuted title/keyword index, directory of researchers, list of journal sources, and a list of generic and common names follow the four sections of bibliography.

Section I, *Biosatellite Flight Experiments,* includes references to experimental design, objectives, observations and results of experiments actually flown in the Biosatellite Program. Section II, *Biosatellite Preflight Studies,* is devoted to research carried out in preparation for planned flights. Bioinstrumentation and data analysis, screening and selection of experiments, engineering and procedural modifications, as well as base line studies are included in this section.

Since this bibliography is focused on the NASA Biosatellite Program, exhaustive coverage of other biological flight experiments was not attempted. However, a selection of references pertaining to other flights carrying biological experiments are included in Section III, *Other Biological Flight Experiments.*

A great deal of information was generated as an outgrowth of biological flight experimentation. Section IV, *Related Research,* lists only a few selected references to this very important body of literature. References to research conducted in the USSR and other countries outside of the United States has been omitted in order to prevent the size of this document from becoming cumbersome.

The author index includes all authors of each reference. Due to format limitations, "et al" was used in the bibliographic citations when there were more than three authors, however, names omitted in the citations are included in the index.

The subject index is derived from rotated titles, and additional keywords taken from the abstract or whole text document. Words such as "biosatellite", "spaceflight", "analysis", and "effects" were not used as index terms. Some attempt has been made to standardize terms in order to simplify the use. However, words appearing in the titles were *not* changed. Both generic and common names of plants and animals appear in the index, but preference was given to the generic name when possible.

We are aware of areas of incomplete coverage, and are equally aware that the user may have very keen interests that go beyond the scope of this bibliography. In order to promote further communication, we have included a directory of the names and addresses of the principal investigators and other key personnel in the Biosatellite Program.

We extend our gratitude and sincere appreciation to Dr. J.F. Saunders for his generous advice and direction, and to the Biosatellite investigators for their contribution of references and reprints. We also wish to acknowledge the following members of the BSCP staff: Morton Werber and Richard Sparks, who prepared many of the abstracts; Linda Gossage and Wanda Fuller, who typed and proofread the manuscript; and Rebekah McKinney, who completed production of the final copy.

Jean E. Pulliam
Biological Sciences Communication Project

1. ABEL, J.H., Jr., D.W. HAACK and R.W. PRICE. 1971.
Effects of weightlessness on the nutrition and growth of *Pelomyxa carolinensis*.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press.]

See #74 for editor's abstract.

2. ADEY, W.R. et al. 1969.
BIOSATELLITE III: Preliminary findings.
Science *166*:492-493.

Physiological deterioration in the male macaque monkey flown in BIOSATELLITE III necessitated its recall after 8.5 days of a planned 30-day flight. For the first 7 days the only telemetered signs of a progressive general decline were falling brain temperature and lowered central venous pressure, which occurred in the last 3 days of flight. Fluid loss in flight was high, caused initially by sweating and later by diuresis, and appeared to arise in the redistribution of blood in visceral pools as a consequence of weightlessness. Death occurred suddenly 12 hours after the flight and was caused by ventricular fibrillation. (Authors)

3. ANONYMOUS. 1969.
BIOSATELLITE II.
National Aeronautics and Space Administration, NASA Facts 3/10-68, Washington, D.C. 12 pages.

BIOSATELLITE II, which orbited for two days, provided data on the effects of weightlessness, weightlessness combined with radiation, and removal from the Earth's diurnal cycle on frog eggs, microorganisms, plants, and insects. The results of these flight experiments were compared with the life processes of control plants and animals on Earth. Mutations and abnormalities in the biosatellite organisms are discussed and interpreted. (M.W.)

4. ANONYMOUS. 1969.
Zero gravity's deadly effects.
Sci. News *96*:393-394.

Factors which contributed to the death of the monkey "Bonnie" aboard BIOSATELLITE III are discussed. Desynchronization of the sleep cycle accompanied by marked fluctuations of heart rate, blood pressure, and respiration was observed early in the flight. Some of the other deleterious factors include: abnormality in the balance mechanism of the ear, loss of 20% of body weight, rise in venous pressure with related fluid loss, loss of calcium, and pooling of blood in the thorax and abdomen. These findings raise questions about the effect of weightlessness on man during extended space flight. (L.M.)

5. BROWNING, L.S. and E. ALTENBURG. 1968.
Effects of the space environment on radiation-induced damage in mature reproductive cells of adult *Drosophila* and in spermatocytes of the immature testis.
Radiat. Res. *35*:500-501.

This abstract indicates results of an experiment conducted on the ground and aboard BIOSATELLITE II designed to show possible effects of zero gravity on *Drosophila*, unirradiated and preflight irradiated mature and maturing sperm cells, and similar cells receiving an additional irradiation in flight. Possible differences were shown in mutation rates; significant differences were shown in losses of some markers, fragment exchanges, and translocation rates between ground and zero gravity groups. Future control experiments on flight factors other than weightlessness are mentioned. (R.M.S.)

6. BROWNING, L.S. 1968.
Effects of the space environment on radiation-induced damage in the reproductive cells of pupae and adult *Drosophila*.
BioScience *18*:570-576.

The frequency of mutations under conditions of space flight in BIOSATELLITE II was compared to those observed in *Drosophila* among concurrent Earth controls. Some of the specimens were exposed to

gamma radiation from ^{85}Sr of 1495r given over the period of 45 hours in orbit. Earth controls received 1466r. A sex-linked recessive lethal mutation rate in mature sperm of 5.07 ± 0.71% (n = 946) was detected among the daughters of the irradiated flight specimens compared to 3.27 ± 0.59% (n = 1039) among the irradiated Earth controls. A highly significant increase ($P < 0.01$) in the frequency of dumpy wing mutants in mature sperm was found between the irradiated and orbited group compared to the irradiated Earth group. (M.W.)

7. BROWNING, L.S. and E. ALTENBURG. 1968.
Effects of the space environment on radiation-induced damage in the reproductive cells of pupae and adult *Drosophila*.
Jap. J. Genet. *43*:461-462.

An experimental group of inseminated female, pupal, and young male *Drosophila* including some previously irradiated was orbited for 45 hours in BIOSATELLITE II. A portion of the material received additional irradiation in flight. These techniques were designed to produce visible mutations in two groups depending on whether effects were detected in mature, stored sperm cells or in sperm cells undergoing maturation. Borderline differences were seen in mutation rates of irradiated mature sperm at zero gravity, and in sex-linked recessive lethals and dumpy wing mutants at 1g. A significant difference in loss of Y markers and a high rate of B fragment exchange between X and Y chromosomes was shown in the flight irradiated group as compared to individuals irradiated on the ground. The preflight irradiated group showed lower Y chromosome/second autosome pair translocations than did controls. Increased X nondisjunction was found in unirradiated flight specimens. Two rare translocations were observed in the nonirradiated flight group. Postflight control experiments on factors other than weightlessness are reported in progress. (R.M.S.)

8. BROWNING, L.S. 1970.
A radiation dose rate effect occurring in developing reproductive cells of male *Drosophila*.
Drosoph. Info. Ser. Res. Notes *45*:63-64.

About 600 specimens of *D. melanogaster* in the late third instar larval stage or the prepupal stage were divided into four lots of 150 each. Twelve hours later one group was subjected to continuous gamma radiation from a Ce^{137} source over a 64-hour period for a total dose of 2000r (0.52 r/min.). Each of the other groups was given 2000r gamma radiation from a Co^{60} source over a period of ten minutes (200 r/min.), one group being irradiated at the beginning of the 64-hour period, another at the middle, and the third at the end of the period. The daughters were tested for lethals. Sex-linked recessive lethals diminished greatly after acute treatments with 2000r applied at the time of pupation, 32 hours later, and 64 hours later. (M.W.)

9. BROWNING, L.S. 1971.
Genetic effects of the space environment on the reproduction cells of *Drosophila* adults and pupae.
In: J.F. Saunders, ed. The Experiments of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

10. BUCKHOLD, B. 1969.
BIOSATELLITE II–physiological and somatic effects on insects.
In: W. Vishniac and F.G. Favorite, eds. Life Sciences and Space Research VII.
North-Holland Publishing Company, Amsterdam. pp. 77-83.

The effects of space flight on *Tribolium confusum*, *Habrobracon juglandis*, and *Drosophila melanogaster* as observed in BIOSATELLITE II experiments are discussed. Wing abnormalities in irradiated *Tribolium* were increased from a value of 29.9% in ground controls to 44.8% in the flown beetles. Reproductive performance for flown female *Habrobracon* was unaffected; postirradiation depression of egg laying was absent in flown, irradiated wasps. Egg production was increased in wasps receiving high radiation doses in flight. Flown males showed disoriented mating behavior for 2 days after the flight. Pooled dose level data revealed longer life span in flown females. Decreased xanthine dehydrogenase (XDH) activity was seen in flight males. No differences were found in F_1 female

progeny of flight and control males. XDH activity of F_1 *Drosophila* males was depressed in progeny of males flown as adults. With males flown as larvae, there was a difference only in the F_1 of irradiated flight specimens. (R.M.S.)

11. BUCKHOLD, B. and J.V. SLATER. 1969.
Effect of temperature and X-irradiation on pupae of the flour beetle, *Tribolium confusum.*
Radiat. Res. *37*:567-576.

The effects of radiation on developmental wing abnormalities and length of the pupal stage were studied in *Tribolium confusum*. The wing abnormality was found to have 2 periods of maximum X-ray sensitivity at 10 and 25 hours postpupation decreasing to control levels at 39 hours. Temperature was also found to be a factor with minimum sensitivity at 28°C. The duration of the pupal stage is increased with decreased temperature or with irradiation. The irradiation delay is independent of temperature. (R.M.S.)

12. CONRAD, H.M. 1968.
Biochemical changes in the developing wheat seedling in the weightless state.
BioScience *18*:645-652.

Seedlings grown in space as part of the Biosatellite Program during a weightless state showed no difference in organ length as compared to those grown on a clinostat or in a stationary erect position. However, less scutella tissue was formed in flight than in ground controls. In the space seedlings, those in a chamber containing 77 ml of air per plant had less scutella tissue than those with 102 ml of air. Differences in carbohydrate metabolism were also noted under the two air conditions. There was a positive correlation between increased peroxidase activity and coleoptile curvature on the clinostat and in space seedlings. There were no significant differences in Michaelis constants or in the maximum velocities of the reactions studied, suggesting that there is no difference in the affinity of the enzyme for the substrate during weightless growth. The clinostat plants and space grown seedlings were similar in gross morphologic response in terms of displacement of the organs from the normal position. But there were differences in glucose-6-phosphate dehydrogenase activity between space grown and either clinostat or erect grown plants. (M.W.)

13. CONRAD, H.M. 1971.
A study of the effect of weightlessness on the biochemical response of a monocotyledonous seedling.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

14. de SERRES, F.J. and B.B. WEBBER. 1968.
The combined effect of weightlessness and radiation on inactivation and mutation-induction in *Neurospora crassa* during the BIOSATELLITE II mission.
BioScience *18*:590-595.

The *Neurospora* experiment on BIOSATELLITE II indicates that for cellular inactivation and induction of recessive lethal mutations, the effects of ionizing radiation under weightless conditions were not different from those in ground-based experiments. The *Neurospora* conidia flown on the surface of Millipore filters were in a relatively inactive state during irradiation; therefore, the results of this experiment should be most directly comparable with results of experiments with metabolically inactive cells. (Authors)

15. de SERRES, F.J. and B.B. WEBBER. 1968.
Genetic effects of ^{85}Sr gamma irradiation on *Neurospora crassa* on the BIOSATELLITE II mission.
Radiat. Res. *35*:499-500.

Samples of *Neurospora* conidia collected on the surface of Millipore filters were irradiated during the flight of BIOSATELLITE II. Postflight comparisons with ground controls showed no significant differences in dose-response curves for survival of heterokaryotic conidia, for induction of lethal

recessive mutations throughout the genome, or for the induction of lethal recessive mutations at the *ad-3*A and *ad-3*B loci. (R.M.S.)

16. de SERRES, F.J. 1969.
Effects of radiation during space flight on microorganisms and plants on the BIOSATELLITE II and Gemini XI missions.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 62-66.

The author summarizes experiments with the lysogenic bacteria *Escherichia coli* and *Salmonella typhimurium*, the bread mold *Neurospora crassa*, and the flowering plant *Tradescantia* on the BIOSATELLITE II and Gemini XI missions. The bacteria were flown in the biosatellite. *Salmonella* showed responses to both weightlessness and weightlessness combined with radiation up to 1630r. Total growth of flight samples was as much as 48% higher in irradiated experimental groups. The frequency of phage P-22 induction was lower in irradiated flight samples than in irradiated controls. Essentially the same results were seen in *E. coli*, but no difference in growth was found between flown and control nonirradiated samples. *Neurospora* went on both missions. No effect was seen for space flight alone on inactivation or mutation. No difference in genetic effects of radiation was seen between flown and ground control samples. Rapidly metabolizing spores on the Gemini XI flight showed less serious radiation effects than did ground controls. Irradiated biosatellite specimens of *Tradescantia* showed increased cell death, pollen abortion, loss of reproductive integrity, and structural and functional abnormalities. (R.M.S.)

17. de SERRES, F.J. and B.B. WEBBER. 1970.
The induction of recessive lethal mutations under weightlessness in the *Neurospora* experiment on the BIOSATELLITE II mission.
Radiat. Res. *43*:452-459.

Samples of asexual spores of a two-component heterokaryon of *Neurospora crassa* collected on Millipore filters were flown on BIOSATELLITE II to evaluate the genetic effects of radiation in combination with weightlessness. Preliminary genetic analyses for cellular inactivation and the overall induction of recessive lethal mutations in the *ad-3* region reported previously indicated that the effects of radiation under weightlessness were not different from those in ground-based experiments. The genetic analysis of the *ad-3* mutations in the flight and ground control samples is now complete; and comparisons have been made between the dose-response curves for the different classes of *ad-3* mutations showing that there is no effect of weightlessness on the spectrum of radiation-induced recessive lethal mutations. These data confirm the negative results obtained with dormant spores flown on Gemini XI. (Authors)

18. de SERRES, F.J. 1971.
Mutagenic effectiveness of known doses of radiation in combination with "zero" gravity on *Neurospora crassa*.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

19. DYER, J.W. 1968.
BIOSATELLITE II operations.
BioScience *18*:555-560.

The preparation and the actual flight of the spacecraft BIOSATELLITE II are described. The author presents a description of the spacecraft, launchpad facilities, and the procedure followed in the final assembly and launch of the vehicle. The scheduled and actual events of the flight and some of the details of the communications network are outlined. (R.M.S.)

20. DYER, J.W., ed. 1969.
Biosatellite Project Historical Summary Report.
NASA/Ames Research Center, Moffett Field, California. 279 pages.

All aspects of the Biosatellite Program are included in this review. Selections of experiments, their development, requirements, constraints and objectives are discussed along with the requirements and constraints placed on the spacecraft. The launch vehicle, launch site, tracking and data systems, and recovery procedures are described. The editor explains the ground control and flight operations and the results of the missions flown. He includes several charts and tables representing the organization, management, funding, and contracts of the program. The interaction between scientists, engineers and project managers, as well as the extremely high cost of any spacecraft program were concluded to be among the major problems encountered. Several recommendations for conducting future biological space projects are made, as a result of the experience gained from the Biosatellite Program. (W.F.)

21. EDWARDS, B.F. 1968.
Gravity receptors and weightlessness.
Anat. Rec. *160*:344.

There is a basic similarity between structures with which various organisms perceive the force and direction of gravity. Gravity receptors have been investigated in tissues subjected to high gravity, to horizontal clinostat motion, and to weightlessness in the Earth-orbiting BIOSATELLITE II, as well as to normal gravity on Earth. The essential elements for appreciation of position relative to the direction of gravity are: granules, cellular or extracellular, of adequate mass to move in response to gravitational changes; hairs, membranes or other structures which are affected by movement of the granules; nerves or chemical mediators which transmit information from receptors to the effectors of the observed response. Cells of wheat seedlings grown in BIOSATELLITE II and fixed while in orbit show a distribution of statolith starch granules similar to that in seedlings grown on a horizontal clinostat in the laboratory, and markedly different from that seen in normal erect grown or centrifuged seedlings. These findings support the view that statolith starch is the gravity receptor in plants. The basic organization of the mechanism is similar to that found in animals. The second element, corresponding to hair cells of the human ear, remains unidentified in plants. It is significant that a horizontally rotating clinostat simulates on a cellular level the weightlessness of an orbiting satellite. (Author)

22. EDWARDS, B.F. and S.W. GRAY. 1968.
Preliminary results from the first successful biosatellite.
Bull. Georgia Acad. Sci. *26*:64.

BIOSATELLITE II was successfully recovered after 45 hours of weightlessness in orbit around the Earth. The flight, planned to last for three days, was shortened as a result of technical difficulties and weather conditions. A package containing 78 growing wheat seedlings was among the 13 experiments designed to study the biological effects of weightlessness alone or in combination with radiation. Wheat seedlings, planted 15 hours before launch, survived the flight uninjured although their roots and shoots were randomly oriented in the absence of gravity. Seedlings fixed in orbit after 43 hours had grown as well as had seedlings of the same age in identical erect or clinostat control packages on the ground. Seedlings returned to Earth alive following the flight had slightly taller coleoptiles than did ground control plants. There is evidence that return to normal gravity stimulated coleoptile growth. The ratio of shoot height to root length shifted so that flight seedlings had coleoptiles longer in proportion to their roots than did erect control seedlings. Statolith starch granules in the cells of seedlings fixed while in orbit had a distribution similar to those grown on horizontal clinostats in the laboratory and markedly different from the distribution seen in erect grown or centrifuged seedlings. These findings support the view that statolith starch granules are the gravity sensors in plants. (Authors)

23. EDWARDS, B.F. and S.W. GRAY. 1969.
BIOSATELLITE II weightlessness experiments.
Bull. Georgia Acad. Sci. *27*:79.

BIOSATELLITE II experiments on the near weightless state with organisms known to have specific responses to gravity are briefly outlined. No differences in frog egg development could be detected.

Amoebae fed normally, and retained normal shape. Growth of orbited amoebae was slower than controls following reentry and recovery, but recovered more rapidly when returned to the erect position. Root and shoot growth in wheat seedlings was not altered by orbit or clinostat; normal gravity possibly accelerated growth when restored. Postflight tests showed that vibration adversely affects lateral root growth. Growth pattern in pepper plants and wheat seedlings on the clinostat was similar to that in orbited plants, though recovery in the orbited pepper plants was slower. (R.M.S.)

24. EDWARDS, B.F. 1969.
Weightlessness experiments on BIOSATELLITE II.
In: W. Vishniac and F. G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 84-92.

The effect of nearly zero gravity on the development of plants and animals was investigated with four experiments on BIOSATELLITE II. No differences were detected in the development of frog (*Rana pipiens*) eggs though a delay of the launch caused the critical first cleavage to transpire on the launch pad. The orbited embryos were slow to reach certain stages of development, but developed normally. Amoebae (*Pelomyxa carolinensis*) fed normally and retained normal shape in orbit. Orbited specimens showed some retarded growth after recovery; electron micrographs detected no abnormalities. Orbited pepper plants behaved comparably to clinostat-mounted controls, but recovered less rapidly than controls when returned to the normal condition. Wheat seedling root and coleoptile growth rates were not significantly altered by flight or clinostat; orientation varied from normal seedlings, but was similar in clinostat and orbited plants. Starch grains showed atypical, random distribution; peroxidase localization varied and its activity was higher in clinostated and orbited plants; five other enzymes showed no differences. (R.M.S.)

25. EDWARDS, B.F. and S.W. GRAY. 1970.
Cellular responses to weightlessness.
Anat. Rec. *166*:301.

A consideration of increase in nuclear size as part of an adaptation mechanism is discussed in relation to changes observed in *Triticum* roots and shoots from NASA BIOSATELLITE II. There were differences in both nuclear volume and mitotic count between flight plants and ground controls. Nuclear volume was measured and mitoses counted on Feulgen stained longitudinal sections of root tips and coleoptiles. The nuclear volume of cells of shoots and roots grown in orbited weightlessness for 45 hours is 13% to 26% greater than that of erect control plants. The differences are significant to $P < .001$. There are fewer mitoses in the roots of plants grown in weightlessness than in either erect or clinostat controls. The difference persists in both primary and secondary roots for as long as 65 hours after satellite launch, and does not appear to reflect a difference in any particular mitotic stage. In spite of the presence of fewer mitoses in the weightless seedlings, their roots were as long as those of the controls. Seedlings grown in both simulated weightlessness on a horizontal clinostat and experiencing vibration comparable to that at launch, have nuclei significantly larger than those of erect, nonvibrated controls. As growth of the seedling organs was not impaired, it is suggested that the increase in nuclear volume is adaptive and not the result of injury. (Authors)

26. EDWARDS, B.F. 1970.
Effects of chronic acceleration on plants.
In: S.A. Gordon and M.J. Cohen, eds. **Gravity and the Organism.**
University of Chicago Press, Chicago. [In Press]

The histology and histochemistry of wheat seedlings grown under different conditions of gravity show interesting variety. Marked rearrangement in the localization of amyloplasts is perhaps the most startling change and can be observed in sections stained with Periodic-Acid-Schiff; seedlings centrifuged show clumping in the base of certain parenchymal cells in the coleoptile, scutellum and root while cells in clinostated seedlings also differ from those of controls grown erect. Increased reactivity of centrifuged tissues has been shown to peroxidase, acid phosphatase and succinic dehydrogenase in centrifuged tissues as compared to controls, which in turn are more reactive than tissues of seedlings grown on the clinostat. These differences will be demonstrated in cross and longitudinal sections. Cell size differences which exist in these tissues are more difficult to evaluate histologically, as are the

effects of temperatures between 15°-30°C on these seedlings. All the organs of the wheat seedlings show growth inhibition after chronic acceleration. However, the differences between centrifuged and control plants is less in plants grown at cooler temperatures than at the optimum of 25°C, since growth at lower temperatures shows some stimulation by acceleration at 150g for the first three days. Higher than optimum temperatures increase growth inhibition more in centrifuged plants. No cytological changes have been observed in their coleoptiles and roots. (Author)

27. EDWARDS, B.F. and S.W. GRAY. 1970.
Effects of weightlessness on mitosis, cell length and nuclear volume in wheat seedlings.
Bull. Georgia Acad. Sci. *28*:s8.

Orbital weightlessness aboard NASA BIOSATELLITE II has been shown to produce changes in orientation, organ length, starch grain distribution and malformations in wheat seedlings. Changes at the cellular level can now be reported. Orbital weightlessness produces a decreased mitotic count in roots, together with an increased root cell length. The increased cell length compensates for decreased rate of division and root length remains normal. Neither decreased cell division nor increased cell length take place in clinostat controls. Orbital weightlessness increases the volume of interphase nuclei in all seedling organs of plants in true weightlessness. In simulated weightlessness (clinostat), nuclear volume is consistently increased only in primary roots. Simulated launch vibration followed by erect growth, or growth on the clinostat, increases nuclear size in roots but not in coleoptiles. Thus, neither the simulated weightlessness of the clinostat, nor simulation of launch vibration, followed by growth on the clinostat exactly duplicate the results of true orbital flight. (Authors)

28. EDWARDS, B.F. and S.W. GRAY. 1971.
Cellular changes in wheat seedlings during orbital flight.
In: W. Vishniac, ed. **Life Sciences and Space Research IX.**
Akademie-Verlag, Berlin. [In Press]

Wheat seedlings in weightlessness aboard NASA BIOSATELLITE II differ from ground control seedlings in mitotic count, cell length and nuclear volume as well as in orientation, starch grain distribution, organ length and malformations previously reported to COSPAR. Dividing cells are fewer in roots of orbited seedlings than in erect or clinostat ground controls. The greatest difference is among cells in early prophase. Root cells, proximal to the zone of cell division are longer in flight seedlings than erect or clinostat ground controls. As the roots are the same length, greater elongation compensates for the reduced rate of cell division. Volume of interphase nuclei in all seedling organs is increased by orbital flight. In clinostat controls, only nuclei of primary roots increase in size. Between 58 and 65 hours of age, nuclear volume in erect, 1g coleoptiles decreases; in flight seedlings it increases. Simulated launch vibration, alone or followed by growth on the clinostat, increases nuclear volume in some roots, but coleoptile nuclei do not respond as in flight seedlings. Thus, at the cellular level, orbital flight cannot be exactly duplicated by the clinostat whether preceded by vibration or not. (Authors)

29. EKBERG, D.R. et al. 1968.
The effects of weightlessness on *Pelomyxa*. II. Nuclear and cellular division.
BioScience *18*:617-622.

The authors describe an experiment designed to show the effects of weightlessness on division in the great amoeba, *Pelomyxa carolinensis*, as compared to static controls performed in conjunction with the orbital flight experiment. No significant differences in division rates were found between inflight and control groups. Starved amoebae did not divide in flight; well-fed flight amoebae showed a possible trend toward a higher division rate during weightlessness. Two amoebae were in mitosis when fixed in weightlessness; all nuclei were in the same phase of division (synchrony). Some interphase nuclei were of irregular shape when fixed during flight. No differences were observed between controls and flight group cell division rates on restoration of the 1g condition. (R.M.S.)

30. EKBERG, D.R. et al. 1971.
Nuclear and cellular division in *Pelomyxa carolinensis* during weightlessness.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Adminitration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

31. GRAY, S.W. and B.F. EDWARDS. 1968.
The effect of weightlessness on wheat seedling morphogenesis and histochemistry.
BioScience *18*:638-645.

Germination of wheat seeds in the Earth-orbiting BIOSATELLITE II was not affected and the growing seedlings showed neither more nor different malformations than did erect grown seedlings on Earth. Coleoptiles of flight seedlings are taller than those of erect control seedlings at 65 hours of age. It is suggested that the stimulus for increased growth is the return to normal gravity at the end of the flight. Growth of roots of flight seedlings is retarded at 58 hours and is comparable to those of erect control seedlings at 65 hours of age. The ratio of shoot height to root length is shifted so that flight seedlings have coleoptiles longer in proportion to their roots than do erect control seedlings. Statolith starch granules were distributed at random in the cells of flight and clinostat control seedlings instead of being clumped on the lower cell wall as in the erect control seedlings. Both flight and clinostat control seedlings appear to have more statoliths than do erect control seedlings. In most dimensions measured, clinostat control seedlings resemble flight seedlings more than they do erect control seedlings. This points up the possibility that the Earth-bound clinostat may be a tool to predict responses to weightlessness in suitable cells, tissues, and organisms. (Authors)

32. GRAY, S.W. and B.F. EDWARDS. 1970.
An effect of weightlessness following exposure to vibration.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VIII.**
North-Holland Publishing Company, Amsterdam. pp. 25-32.

Vibration of germinating wheat seedlings at the levels experienced during the launch of the BIOSATELLITE II increases the frequency of developmental arrest in seedling organs. Severe vibrations lasted approximately 30 sec. in two stages. Power spectral density was greatest at frequencies around 15-16 and 19-22 Hz on the entire vehicle. Vibration forces reaching the affected parts of individual seedlings could not be measured. One or more seedling organs may be expected to be absent in 11% of selected Earth-grown wheat plants. If subjected to simulated launch vibration between 12 and 27 hours after the start of germination, the number of abnormal plants rises to 21.6%. Lateral roots are most affected by vibration at this age. Seedlings which went into orbital weightlessness aboard BIOSATELLITE II, or were grown for several days on a horizontal clinostat after vibration, showed only 5.3% abnormalities. Simulated weightlessness on the clinostat without prior vibration did not alter the number of abnormal plants. It is suggested that growth in weightlessness following exposure to vibration permits more extensive repair of injury produced by vibration than does growth in Earth's gravity. (Authors)

33. GRAY, S.W. and B.F. EDWARDS. 1971.
The effect of weightlessness on the growth and orientation of roots and shoots of monocotyledonous seedlings.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

34. GROSCH, D.S. 1968.
Habrobracon life span, egg deposit and hatchability after two days of gamma ray exposure of females during orbit in BIOSATELLITE II.
Radiat. Res. *35*:546.

All braconid females were alive when BIOSATELLITE II was unpacked. Only rare exceptions failed to survive the subsequent 20 days of study. Furthermore, at every dose level, mean life span showed a slight tendency to exceed values for females of the ground control. Usually after a series of radiation doses, a family of oviposition curves results, which reflects the vulnerability of differentiating cells in a valley that deepens and broadens with increased dose. The ground experiment females exposed to a duplicate of the satellite's ^{85}Sr source provided the expected pattern of response. Orbited females oviposited in a strikingly different pattern. Instead of a valley there was a sloping plateau which exceeded the values on the 10th day. Eggs laid later in life compensated for the earlier low

productivity. Hatchability records differ according to the cytological condition, during flight, of the cells from which eggs were derived for later deposit. Metabolically active oocytes which developed into eggs the 3rd day showed synergistic effects of space flight factors in conjunction with radiation; but during the first week of oviposition, hatchability improved until it exceeded the levels of comparable ground exposures. Subsequently, during the weeks of compensatory egg deposit, the hatchability was exceptionally high. Difference between dose levels disappeared and antagonism rather than synergism predominates in this measure of the response of a progenitive tissue. (Author)

35. GROSCH, D.S. 1968.
Reproductive performance of female braconids compared after brief and protracted exposures to ionizing radiations.
In: Isotopes and Radiation in Entomology.
International Atomic Energy Agency, Vienna. pp. 377-390.

Three criteria of damage can be employed in radiation experiments with female braconids. Egg production records provide a measure of the gross chromosomal and nuclear damage to a variety of cell types. Egg hatchability reveals more subtle damage, both genic and age related. Life span records reflect the ability of somatic tissues to function for general body maintenance. The shape of the egg production curve is discussed from the standpoint of appreciating the cytology of the insect ovariole. Hatchability data are analyzed with respect to the stage of embryonic development achieved in unhatched eggs. Large-scale experiments performed in conjunction with the first and second U.S. biosatellite experiments provided striking evidence of a deferred low period of egg production from protracted gamma ray doses delivered in ground experiments; no pronounced low for females recovered from space flight; and of both dose-dependent and age-influenced components of embryonic lethality. (Author)

36. GROSCH, D.S. 1970.
Egg production and embryo lethality for *Habrobracon* from BIOSATELLITE II and associated postflight vibration experiments.
Mutat. Res. *9*:91-108.

The effects of weightlessness on radiation-induced changes in egg production and larval development in the female braconid wasp were studied on BIOSATELLITE II and in a series of control experiments using the recovered vehicle subjected to similar radiation and to simulated forces of launching and recovery. A characteristic radiation-induced decrease in egg production was cancelled by orbital flight; this decrease was only slightly alleviated by simulated flight. Fecundity was above normal in orbited wasps. The only evidences of low hatchability were from eggs in the first meiotic metaphase during orbital flight and from eggs deposited on the third day after recovery which were represented by an ordinarily invulnerable cell type during the flight. Otherwise the eggs had excellent hatchability even during maximum sensitivity periods. Controls showed the usual pattern of response except for moderate alleviation of the post-fifteenth day senile decline. No cleavage failure deaths were seen during periods of excellent hatchability of biosatellite wasps; deaths occurred in a variety of stages from the simulated flight. These facts and the somatic fitness of the experimental wasps are interpreted as an indicator that packaged inactivity and weightlessness provides an opportunity for repair of radiation lesions. The same condition may be deleterious to the oocyte-nurse cell complex. (R.M.S.)

37. HARMOUNT, T.H. 1968.
Measurement of space environment effects on biological specimens.
In: Proceedings of the Fifth Space Congress, Vol. I.
Canaveral Council of Technical Societies, Cape Canaveral. pp. 3.5-1 - 3.5-5.

Some of the major areas of interest in the biosatellite experiments are as follows: studies of weightlessness effects in living organisms; the combined effects of reduced gravity and radiation; periodicity studies away from the Earth's influences; and the behavior of animals under stress. The problems encountered in these studies include perishability of live specimens, effects of the "hard environments" of launch, environmental control, and life support. The various biosatellite missions are described. The 3-day missions were concerned with the effects of weightlessness on the growth of various kinds of seedlings, the mutagenic effects of gamma irradiation, embryonic differentiation and

development in space, and the induction of lysogenic bacteria in space. The 30-day mission included an instrumented restrained primate, who was measured by an EKG, EEG, ZPG, EOG, GSR, and EMG. Its core temperature was also recorded. Brain functions and performance under prolonged weightlessness, cardiovascular and metabolic processes, and bone density changes were studied during the flight. The 21-day mission is concerned with the effects of the space environment on the gross body composition of the rat and its rhythmicity, plant physiology and morphology, and isolated human cells. (M.W.)

38. HEWITT, J.E. 1968.
Radiation exposures during the BIOSATELLITE II flight.
BioScience *18*:565-569.

Experiments regarding radiation exposure of biological material in BIOSATELLITE II are described. The biological specimens were divided into four groups; two were simultaneously exposed aboard BIOSATELLITE II and in an Earth-control capsule to radiation and to weightlessness, while the other two groups were not irradiated. The radiation source was a ^{85}Sr gamma emitter giving off a simple ray of 0.513 MeV energy; the half-life of the source was 64 days. The delivered doses were in agreement with an exposure time of 42 hours instead of the normal 65 hours. The radiation exposure in the control areas was quite low, as determined by lithium fluoride readings, with few above 0.5r. Nuclear emulsion measurements were made of the number of protons and heavy ions entering the spacecraft during orbital flight. The upper limit for the mission dose due to protons was 40 millirads. There were 10.1 traversals of atomic nuclei of $Z \geqslant 20$ through each cm^2 during the flight. With respect to the radiation environment, the conditions for a successful experiment were met. (M.W.)

39. HEWITT, J.E. 1971.
Radiation exposures during the BIOSATELLITE II flight.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

40. JOHNSON, S.P. 1968.
Biochemical changes in the endosperm of wheat seedlings in the weightless state.
BioScience *18*:652-655.

The purpose of this study was to determine if the endosperm, a storage organ, would produce metabolic changes in the wheat seedling following exposure to the low level of gravity encountered during orbital flight. Analysis of carbohydrates, amino acids, and nitrogen fractions of the endosperms did not show an effect of 45 hours of orbital weightlessness (BIOSATELLITE II) when compared to Earth control samples. It had been hoped that the longer coleoptiles, representing a higher degree of sensitivity to geoinduction, would demonstrate a change in metabolism of the endosperm attributable to orbital weightlessness. (M.W.)

41. JOHNSON, S.P. and T.W. TIBBITTS. 1968.
The liminal angle of a plagiogeotropic organ under weightlessness.
BioScience *18*:655-661.

Four pepper plants, *Capsicum annuum*, were orbited at 10^{-5} g for 45 hours on BIOSATELLITE II; a comparison of inflight photographs and clinostat controls was shown with a teleredex machine. The results were similar. However, some of the clinostat plants showed more petiole movement which preliminary analysis indicates is significant. Carbohydrate and amino acid content in leaves, stems, and growing points of plants were analyzed. Results indicate that mobilization occurs as a response to both clinostat rotation and weightlessness and that carbohydrates and amino acids play an important role in geoinduction. (R.M.S.)

42. JOHNSON, S.P. 1971.
Biochemical changes in the endosperm of wheat seedlings.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

43. JOHNSON, S.P. and T.W. TIBBITTS. 1971.
The liminal angle of a plagiogeotropic organ under weightlessness.
In: J. F. Saunders, ed. The Experiments of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

44. LOOK, B.C. 1968.
BIOSATELLITE II experiment environment.
BioScience *18*:560-564.

The experiment capsule, heat shield, and the thrust cone or retrorocket assembly are described as part of the BIOSATELLITE II experiment environment and the reentry vehicle. Polypropylene or Lexan was used for the experiment packages, which had aluminum brackets and supports. Attached to each package was one or more thermistors and lithium fluoride radiation dosimeters. An atmosphere comparable to that of Earth at sea level was maintained inside the experiment capsule, and checked through samples taken before final closure of the capsule prior to launch and before its opening after recovery. Measurement of radiation, acceleration, vibration, and noise within the experiment capsule is described. The ground control tests during the flight are also mentioned. The spacecraft provided a suitable laboratory for the biological experiments, and all of the specimens were recovered in good condition. (M.W.)

45. LYON, C.J. 1968.
Gravity and the upright plant.
Yale Sci. Mag. *43*:6-9.

Identical growth rates and patterns of leaves and roots in the BIOSATELLITE II experiments and in the ground control experiments on horizontal clinostats have confirmed the reliability of the clinostat method for studies in geotropism and related phases of growth physiology. From research using this old device and modern methods for analysis of auxin transport in plant organs, we can now explain with confidence the paradoxical situation that plants grow upward and easily produce heavy leaves and branches as lateral appendages in spite of the gravitational force that tends to topple such a structure. The gravitational force that would appear to be a handicap to maximum interception of solar energy by exposure of a deep, wide spreading layer of green tissues to sunlight has been turned into an asset for efficiency. The upright plant was made possible by one evolutionary mechanism which uses gravity to keep young stems growing up by drawing a hormone downward within them. A second mechanism for hormone transport causes some of the same growth regulator to be moved upward to lateral organs and thereby restrict upward growth of the organs. (Author)

46. LYON, C.J. 1968.
Growth physiology of the wheat seedling in space.
BioScience *18*:633-638.

A biosatellite experiment on wheat seedlings grown without a gravity effect is reported. The growth and development of wheat seedlings in their early stages during orbital flight were not disturbed enough by the absence of gravitational force to be reflected in the growth rates or external morphology of roots or coleoptiles. There appeared to be an independence from the gravitational force of the intracellular movement of certain organelles which carry key enzymes to the sites of energy release and use. The absence of gravitational force within wheat seedling organs had no measurable effects on the endogenous mechanisms for production and distribution of auxin. (M.W.)

47. LYON, C.J. 1968.
Plagiotropism and auxin transport.
In: Y. Vardar, ed. Transport of Plant Hormones.
North-Holland Publishing Company, Amsterdam. pp. 251-292.

In a detailed discussion of the subject of plant growth form as a function of auxin transport, the author describes the results of an experiment flown aboard BIOSATELLITE II in which 73 wheat seedlings

were germinated and grown in the virtual absence of gravity. Control sets of seedlings were germinated on the horizontal clinostat and otherwise subjected to the same set of conditions as the orbited group. The results of comparisons between the 2 sets of seedlings show no significant differences in growth rates or orientation angles of seedling organs. (R.M.S.)

48. LYON, C.J. 1968.
Wheat seedling growth in the absence of gravitational force.
Plant Physiol. *43*:1002-1007.

BIOSATELLITE II was in orbit for nearly two days to permit experimental study of the growth physiology of wheat seedlings. Selected embryos were planted in special holders to produce sets of seedlings with organs free of mechanical disturbance. The experimental package consisted of four plastic cylinders fitted with a thermistor. One large cylinder provided space and a moist sea-level atmosphere around three sets of seedlings. Of the other three chambers with one seed holder each, two were equipped to spray-fix their seedlings with formalin, acetic acid, and alcohol before the package was returned from orbit. The absence of gravitational force within the organs of a seedling seems to have no effect on the basic growth processes and biochemical reactions which control the rates of meristematic activity. (M.W.)

49. LYON, C.J. 1971.
Growth physiology of the wheat seedlings in space.
In: J.F. Saunders, ed. The Experiments of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

50. MARIMUTHU, K.M., A.H. SPARROW and L.A. SCHAIRER. 1970.
The cytological effects of space flight factors, vibration, clinostat and radiation on root tip cells of *Tradescantia*.
Radiat. Res. *42*:105-119.

Cytological effects of actual and simulated space flight factors, with and without gamma irradiation, have been studied in *Tradescantia* clone 02. In the BIOSATELLITE II experiment, one package of 32 rooted *Tradescantia* inflorescences was exposed during the weightless phase to about 220 R of γ-radiation from a ^{85}Sr source, and an unirradiated package was used as a flight control. Two similar packages, one irradiated and the other unirradiated, were maintained in a nonflight vehicle at the Cape Kennedy launch site as nonflight controls. The location of the roots of individual plants within the package relative to the radiation source permitted an exposure-response determination for chromosome aberrations. In the clinostat-radiation experiments dose response data were not obtained. After the treatments, the frequencies of chromosomal aberrations and mitotic spindle abnormalities were studied in root tip cells. A comparison between the irradiated flight and nonflight samples and between the irradiated clinostat and erect materials showed no significant difference in total chromosome aberration frequency or in single or multiple break aberrations. No increase in chromosome aberration due to random vibration was observed. A significant increase in the frequency of cells having abnormal nuclei resulting from the presumed malfunctioning of the mitotic spindle was noticed in all of the flight samples over the frequency observed in the nonflight samples. No such increase was observed either in vibration or in clinostat experiments, thus suggesting an effect of weightlessness on spindle function. (Authors)

51. MARIMUTHU, K.M., L.A. SCHAIRER and A.H. SPARROW. 1970.
The effects of space flight factors and gamma radiation on flower production and microspore division and development in *Tradescantia*.
Radiat. Bot. *10*:249-259.

The effect of the interaction between ^{85}Sr gamma radiation (average exposure approximately 220 R) and space flight factors (vibration, acceleration, weightlessness, etc.) on the number of flowers produced and on microspore division and development was studied in BIOSATELLITE II. In the actual flight one package of 32 young *Tradescantia* clone 02 plants was irradiated during the two-day flight,

and another package was used as an unirradiated flight control. Two similar packages, one of which was irradiated, were maintained as nonflight controls in a similar spacecraft at the launch site. Various postflight experiments were conducted in an attempt to attribute the effects observed in the orbital plants to specific flight factors. In these postflight ground tests plants were grown simultaneously in both the flight and nonflight spacecraft under conditions similar to those recorded during the actual flight. In the clinostat and additional vibration experiments, individual packages rather than the whole spacecraft were used. After each treatment, young flower buds were collected for at least 26 days. Some of the morphological and cytological effects observed in the flight material can be attributed to low gravity (weightlessness) and others to the internal environment of the spacecraft. Those effects attributed to weightlessness include: an increase in number of flowers produced in both orbited samples compared with their nonorbited controls; and various kinds of mitotic abnormalities associated with altered spindle behavior in microspores. Effects attributed to spacecraft environmental factors such as the increased concentration of ethylene measured in the flight vehicle include: an increase in the mortality rate of microspores; an increase in the frequency of developmental abnormalities indicated by a change in the number and shape of the nuclei in young pollen; and an increase in flower bud "blasting" which led to a change in the pattern of flower production. (Authors)

52. MARWICK, C. 1968.
Bad news for astronauts.
New Scientist *37*:462-463.

Experiments of BIOSATELLITE II involving both lower plants and animals are summarized. It is observed that the weightlessness of space can magnify the effect of radiation on living matter up to four times, suggesting that current safety levels for radiation exposure in manned space flights are insufficient and should be increased. Radiation seems to exert its greatest effects on young, rapidly dividing cells, or in cells actively reproductive. There is also evidence that the growth and metabolism of rapidly dividing cells are slowed by the absence of gravity. Vinegar gnats were found to have almost four times the mutation rate of gnats irradiated on Earth, and there was an unusual derangement of chromosomes in the larvae. In flour beetles, twice as many lethal mutations occurred in the offspring of those in space than in ground beetles. Wasp eggs irradiated on the flight recovered faster and with less damage than those irradiated on the ground. No differences have as yet been found between flight specimens of orange bread mold and ground controls. Two strains of lysogenic bacteria grew faster in space, but had less effective latent viruses. The spiderwort plant suffered greater cell death and abortion of pollen after irradiation in space, but no differences were observed between pepper plants in space and on the clinostat. Weightlessness seemed to have little influence on the development of frog eggs or on amoebae. (M.W.)

53. MATTONI, R.H.T. 1968.
Effects of space flight and radiation on growth and induction of lysogenic bacteria.
Radiat. Res. *35*:499.

A total of 46 replicate cultures of *Salmonella typhimurium* and *Escherichia coli* were used in a test of spacecraft and radiation interaction. Experimental (flight) populations reached higher densities than controls, and complex interactions of spacecraft factors and radiation were indicated. Virus induction by P-22 phage was lower in flown populations. (R.M.S.)

54. MATTONI, R.H.T. 1968.
Space-flight effects and gamma-radiation interaction on growth and induction of lysogenic bacteria.
BioScience *18*:602-608.

Comparison of results of two strains of lysogenic bacteria orbited in BIOSATELLITE II and otherwise grown under nearly identical conditions on Earth conclusively show significant effects of space flight on several fundamental biological processes. Although the two strains grew at different rates, both produced significantly higher mean densities as a consequence of flight. The particular factor of space flight responsible is most likely reduced gravity, since growth of *Salmonella typhimurium* BS-5 (P-22)/P-22 was complete to stationary at reentry. *S. typhimurium* also yielded relatively greater densities under gamma irradiation (48%) than without radiation (19%). The relatively more dense irradiated sets may be ascribable, in part, to temperature effects as well as to the possibility of more

efficient repair of radiation damage. Phage P-22 yield was also significantly affected by space flight. Like the bacteria population densities, phage yield was differentially influenced by radiation during space flight compared with the Earth environment. When expressed as the ratio of free phage per space viable bacterium, yield decreased with increasing radiation in the space flight cultures. The ratio of phage to bacteria density is consistently lower in flight populations. If the relative number of phage produced per bacterium is constant, then these data indicate induction is less frequent during space flight. The data for *Escherichia coli* C-600 (λ)/λ are partially inconsistent, although the cell density results generally agree with those for *S. typhimurium*. A part of the inconsistency may be a function of the lower growth rate of *E. coli*, which was still in exponential growth phase at recovery. It is believed that the greater bacterial densities were a function of random cell distribution in the liquid medium under reduced gravity conditions. Such distributions would increase the efficiency of nutrient transfer into and waste transport from the cell. The lower yield of bacterial virus in the flight cultures by this mechanism cannot be explained. (Author)

55. MATTONI, R.H.T. et al. 1971.
Induction of lysogenic bacteria in the space environment.
In: J.F. Saunders, ed. The Experiment of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

56. MEEHAN, J.P. 1971.
BIOSATELLITE III: A physiological interpretation.
In: W. Vishniac, ed. Life Sciences and Space Research IX.
Akademie-Verlag, Berlin. [In Press]

On June 28, 1969, a macaque monkey was boosted into orbit for a projected 30-day flight. It was aborted after 8½ days and the monkey died 16 hours later. Data collected indicate that weightlessness and hypothermia acted to shift blood volume centrally. This provided a strong drive for the reduction of blood volume. Restraint, unusual vestibular sensations, and the continuing polydipsia all acted to disturb the central mechanisms affecting salt and water metabolism. It is probable that the function of the kidney was significantly affected and that an excessive amount of salt was lost. It appeared that a serious electrolyte disturbance was superimposed on growing dehydration. Unpleasant vestibular sensations may have contributed to the high evaporative loss by autonomic disturbance. The whole problem was compounded and reinforced by the unnatural restraint to which the monkey was subjected. (Author)

57. OSTER, I.I. 1968.
Effects of weightlessness on radiation-induced somatic damage in *Drosophila* larvae.
BioScience *18*:576-582.

A report is presented which focuses on qualitative aspects of data obtained from first instar *Drosophila* larvae flown on BIOSATELLITE II. Mortality of flown, irradiated young larvae was higher than irradiated ground controls, though ground-based experiments involving acceleration, shock and vibration yielded results similar to nonirradiated flight specimens. Partial count of material prepared to show chromosome bridges and breaks indicates significantly more damage in the flown, irradiated group. There is also indication of a disjunction failure in both irradiated and nonirradiated flown groups. Mating experiments using flown males and appropriate tester females have revealed 4 translocations in 508 tests from the flown material and none in 1206 tests of ground-based controls. The author concludes that weightlessness brings about a nullification of some of the cell's repair processes, possibly on a physical level, although there is no evidence ruling out biochemical interference. (R.M.S.)

58. OSTER, I.I. 1968.
Genetic effects of zero gravity and radiation.
Jap. J. Genet. *43*:462-463.

One major goal of the BIOSATELLITE II mission was to investigate the possible interactions between ionizing radiation and zero gravity at the level of the genetic material. In addition to the carefully

controlled and monitored environmental conditions maintained throughout the 45 hours of Earth-orbital flight, BIOSATELLITE II was unique in that part of the live material could be exposed to several hundred roentgens of readily measurable gamma radiation from an on-board strontium source. Ground-based irradiated and unirradiated individuals served as controls. Subsequent analyses involved observations of the somatic damage among the survivors and the use of specially synthesized stocks to determine the effects on their offspring. Techniques, to insure that homogeneous stages of cell development were being compared, were used throughout the work. Cytogenetical analysis of the material has revealed the following results of significance: radiation interacts with weightlessness to produce more killing chromosomal breakage followed by loss or exchange of elements, and sex-linked recessive lethal mutations in actively growing and metabolizing individuals than in those irradiated on Earth; and some factor, associated with space flight, perhaps weightlessness, vibration, cosmic radiation or a combination of some or all of these, is capable of causing improper chromosome separation (nondisjunction) and the formation of chromosomal translocations. The mechanism involved in the formation of the latter is currently under investigation. The bearing which these findings have on problems associated with developmental processes and repair of genetic damage is discussed. (M.W.)

59. OSTER, I.I. and D.E. GOOD. 1968.
Irradiation of *Drosophila* under space flight conditions.
Radiat. Res. *35*:500.

Observations on *Drosophila* flown aboard BIOSATELLITE II are briefly reported in preliminary form. Orbited, irradiated larvae show somewhat higher mortality than ground-irradiated specimens. More mature individuals tend to be unaffected even by radiation alone. Chromosome breakage and bridge formation indicate some effect of radiation plus weightlessness. All flight specimens showed evidence of induced nondisjunction. (R.M.S.)

60. OSTER, I.I. 1969.
Genetic effects produced by the space environment.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 95-96.

The author indicates the suitability of *Drosophila melanogaster* as a test organism for observing the effect of the space environment on animals, and then describes the results of cytogenetic analyses on *Drosophila* larvae flown with BIOSATELLITE II. Significant results noted are more premature aging, more chromosomal breakage and loss, and more recessive lethal mutations in actively growing individuals caused by radiation in the space environment than in irradiated ground controls. Also, some factor, probably weightlessness, causes chromosomal nondisjunction and chromosomal translocations. (R.M.S.)

61. OSTER, I.I. 1970.
Effects of the space environment on the somatic and reproductive cells.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VIII.**
North-Holland Publishing Company, Amsterdam. p. 4.

Data from larval and mature fruit flies *Drosophila melanogaster* recovered from BIOSATELLITE II show that some factor(s) associated with the space flight alone and in combination with ionizing radiation enhances genetic errors as much as 100%. Some observations indicate that factors other than weightlessness were contributory; however, analysis of a large quantity of data definitely shows weightlessness to be a factor in the observed responses. Extensive postflight simulations have ruled out vibration and shock as factors in the genetic damage to adult flies. Therefore it is concluded that radiation and weightlessness produce higher mortality, more chromosomal breakage, and more sex-linked recessive lethal mutations than seen in ground-irradiated controls. Weightlessness, possibly alone, is responsible for nondisjunction and the formation of translocations. (R.M.S.)

62. OSTER, I.I. 1971.
Genetic implications of space flight.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

63. PRICE, R.W. and J.H. ABEL, Jr. 1968.
The effects of weightlessness on *Pelomyxa*. III. Digestion, growth, and locomotion.
BioScience *18*:622-632.

The effects of the space environment on feeding, growth, and morphology were studied in amoebae that were starved for periods from 27 to 75 hours or were continuously fed. Of the 1280 amoebae launched into space as part of the BIOSATELLITE II experiments, 1142 were recovered; 814 of them were fixed at various time intervals during the flight and 328 were returned alive. From the analysis completed to date, the following conclusions are made: survival and growth of *P. carolinensis* were essentially unchanged as a result of weightlessness; physiologically and morphologically amoebae subjected to weightlessness were not significantly different from the Earth-control organisms; preliminary cytochemistry results indicate little or no difference as a result of weightlessness on digestive processes; food vacuole data indicates that ingestion of paramecium was somewhat accelerated, although the rate of digestion of food vacuoles might have been slightly depressed during weightlessness; and growth rates in flight amoebae, although somewhat reduced during weightlessness, appeared to accelerate at around the time of reentry. (Authors)

64. REYNOLDS, O.E. and J.F. SAUNDERS. 1968.
BIOSATELLITE II. Preliminary scientific observations.
Curr. Mod. Biol. *2*:147-157.

The experimental results showed convincingly that there is an interaction between radiation and one or more other factors encountered in flight. This interaction varied between increasing the effects of radiation 4-fold to decreasing the effect slightly but significantly. Whereas several of the experiments had a background of control studies assuring that vibration alone could not have been the only interacting factor, other experiments did not have sufficient control data. For this reason it was agreed that further postflight earth control studies must be done to interpret this phenomenon fully. The set of experiments for study of the biological effects of weightlessness alone showed a close correspondence to results obtained by exposure to rotation on the clinostat. The clinostat exposure, in its simplest form, consists of rotating a plant in horizontal position (normal to the direction of the force of gravity) at a rate of rotation sufficient to prevent the plant from responding normally to gravity in any one direction. (Authors)

65. REYNOLDS, O.E. 1968.
The bioscience programs of NASA.
In: H. Buecker, ed. **Extraterrestrial Biophysics, Biology, and Space Medicine.**
Johann-Wolfgang-Goethe-Universitat, Frankfurt. pp. 19-42.

Several features and actual flight data from biosatellite experiments are included in a discussion of the Bioscience Program. Mentioned also are details of Wolf Trap and Gulliver. (R.M.S.)

66. REYNOLDS, O.E. 1969.
BIOSATELLITE II mission.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 49-61.

In BIOSATELLITE II, the scientific payload consisting of thirteen selected general biology and radiation experiments was subjected to planned, carefully controlled environmental conditions during 45 hours of Earth-orbital flight. The decision was made to abbreviate the scheduled 3-day mission by approximately one day because of a threatening tropical storm in the recovery area, and a problem of communication with the spacecraft from the tracking stations. Highest priority was placed on recovery which was essential to obtain the scientific results on all the experiments. The operational phase of the mission came to a successful conclusion with the deorbit of the recovery capsule, deployment of the parachute system and air recovery by the United States Air Force. The 127 kg recovery capsule was returned to biology laboratories at Hickam Air Force Base, Hawaii, for disassembly and immediate inspection and analysis of the biological materials by the experimenters. It was evident immediately that the quality of the biology was excellent and this fact gave promise of a high return of scientific data. The environmental conditions provided to the experimental material in the spacecraft, provisions

for experimental controls, and operational considerations are presented as they related to interpretation of the experimental results. (Author)

67. REYNOLDS, O.E. and J.F. SAUNDERS. 1971.
The conclusions of the BIOSATELLITE II experiment.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

68. SALISBURY, F.B. 1969.
Expected biological responses to weightlessness.
BioScience *19*:407-410.

Four general categories of response to weightlessness are described. The first is gross and readily understood responses to weightlessness which includes the effect on the kinesthetic sense of muscles pulling on bones and organs pulling on their supporting membranes. The second is long-term results of gross gravity responses to weightlessness involving changes in social behavior or changes in metabolism which would not be readily apparent. The third category deals with effects on cellular metabolism and subsequent growth and response. The principal question in predicting response at the cellular level is whether or not the cellular contents can be influenced by gravity, specifically the 1g level at the Earth's surface. The cellular phenomena that might respond to gravity (1g on Earth, clinostat, weightlessness on a satellite, and 1g on a centrifuge) are diffusion, convection due to gravity, convection due to streaming, active mixing, and asymmetrical distribution of particles. The last category includes gross biological effects due to responses at the cellular level, as exemplified by plant geotropism. (M.W.)

69. SAUNDERS, J.F., ed. 1968.
The BIOSATELLITE II experiments, 1967, preliminary results, February 1968.
BioScience *18*:538-661.

A total of 28 papers representing a symposium on the preliminary findings of BIOSATELLITE II are reproduced. Ten papers are devoted to orientation, history, description of the spacecraft, log of the mission and overall experimental design. The remaining papers represent actual findings of the experimenters concerned in the BIOSATELLITE II mission. Abstracts of individual papers may be found in this bibliography indexed under the authors' names. (R.M.S.)

70. SAUNDERS, J.F. 1968.
Biosatellite Program.
In: B. Berman and D.W. Jenkins, eds. **Space Bioscience: Significant Achievements in Space Science 1967.**
National Aeronautics and Space Administration, NASA SP-167, Washington, D.C. pp. 95-121.

The findings and expertise of space and planetary biology are utilized to examine the characteristics of the space environment and their effects on biologic organisms, and to search for evidence of extraterrestrial life, study its origin and nature, and formulate basic theories and models of the origin of life. To provide a basis for protection against the hazards of weightlessness and radiation in space, plant and animal experiments are being conducted in space on physiologic changes, metabolic disturbances, biorhythmic derangements, and systemic disruptions. Research concerning chemical evolution, extraterrestrial life, spacecraft sterilization and planetary quarantine, environmental biology, and behavioral biology is discussed. The outstanding achievement in 1967 was the successful flight and recovery of BIOSATELLITE II which carried 13 scientific experiments. The preliminary results are presented. (Author)

71. SAUNDERS, J.F. 1968.
The effects of gamma radiation combined with weightlessness on biologic system in BIOSATELLITE II.
Radiat. Res. *35*:498-499.

In this abstract of an introductory paper given at a biosatellite symposium, the author outlines the basic concept of the BIOSATELLITE II mission as the determination of the effects of known quantities of radiation combined with weightlessness on a variety of living organisms. He identifies organisms used in seven reliable experiments which illustrate that radiation effects are indeed altered by the space environment. (R.M.S.)

72. SAUNDERS, J.F., O.E. REYNOLDS and F.J. de SERRES. 1970.
The experiments of BIOSATELLITE II.
In: S.A. Gordon and M.J. Cohen, eds. **Gravity and the Organism.**
University of Chicago Press, Chicago. [In Press]

The design, objectives and findings of experiments flown on BIOSATELLITE II are discussed by administrative and research scientists responsible for the success of the project. The authors point out that development and utilization of a spacecraft as a unique instrument for the study of biological phenomena subjected to radiation, weightlessness and other space flight factors was dependent on concentrated multidisciplinary scientific effort. While many fundamental biological and developmental processes appeared to be unaffected by space flight, evidence was obtained that some factor, probably weightlessness, induced biological alteration which could not be duplicated in ground-based experiments conducted on the clinostat. The synergistic effect of radiation and weightlessness was clearly observed especially on the process of mutagenesis. Preflight and postflight experiments and ground-based controls played a critical part in the evaluation and understanding of the flight experiment. BIOSATELLITE II, intended as a pilot study, can serve as a foundation for the design of experiments to be carried out on future manned and unmanned space flights, orbital laboratories and planetary missions. (R.M.S.)

73. SAUNDERS, J.F., O.E. REYNOLDS and G.D. SMITH. 1971.
BIOSATELLITE II–The nation's first biology laboratory in space.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

74. SAUNDERS, J.F., ed. 1971.
The Experiments of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

The history, the experiments and the scientific conclusion of the BIOSATELLITE II space biology laboratory are presented in this volume. The chapters dealing with individual experiments constitute final reports dealing with preflight baseline information, the hypothesis and design of the experiment, the flight hardware, the analysis of data from the flight and its translation into information that was further challenged by postflight tests. The latter were performed to separate the inputs of variables such as acceleration and vibration in those cases where vagaries or ambiguities precluded, possibly, the interpretation of actual weightlessness effects. The thirteen experiments of BIOSATELLITE II were concerned primarily with a broad spectrum of biologic phenomena, encompassing more than 100 well established biologic end points. Hypotheses were advanced relative to the ability of living systems to maintain normal organization and function during exposure to the space environment. Scientific curiosity centered about the biologic changes that might occur in gravity-dependent life processes due to the absence of Earth's gravity and rotational periodicity. A major issue evolved about the question of whether weightlessness and quantified gamma radiation from an on-board 85-strontium source would act synergistically, antagonistically or not significantly interact in imposing any biologic effect. Results are presented of observations on the selected end points representing the molecular, cellular and systems levels of biologic structure and physiologic function. In general, the wheat seedling, pepper plant, amoeba and frog egg experiments deal with the effects of weightlessness on: (a) alterations of universal biochemical pathways; (b) disruption of normal mitotic sequences; (c) changes in morphogenesis, growth and development; and (d) orientation and locomotion with respect to the hypogravity environment. Larvae and adults of *Drosophila melanogaster*, *Tradescantia* clone (02), *Escherichia coli*, *Salmonella typhimurium*, *Neurospora crassa*, *Tribolium confusum*, and *Habrobracon juglandis* made up the BIOSATELLITE II population used to study genetic and somatic changes, meiotic and mitotic

aberrancies, longevity, survival and population dynamics, which were the general phenomena of experimental concern in the weightlessness-radiation experiments. For instance, no effect of a gravity-free field, combined with radiation or alone, was expected on such well defined, well chosen characteristics as dominant lethality, chromosome translocation frequency and recessive lethality. However, it was postulated that since these effects can be precisely quantitated, any unexpected synergistic effect could be detected readily. As described, the evidence from several experiments indicates that there is significant synergism between radiation and weightlessness. There is evidence of antagonism by weightlessness of radiation-induced abnormality. Results such as increased frequency of chromosome translocation, less malformation in seedling organs, increased and decreased enzyme activity, lowered mitotic rates and disturbed mitotic spindle are considered to be significant expressions of weightlessness, by itself, at the molecular and cellular levels of organization. Many of the results in the space-borne plants were *not* duplicated in the Earth-based clinostat controls, therefore, tending to dispel the belief of some botanists that the clinostat tends to duplicate weightlessness. The results of these experiments emphasize the need for more Earth-based research on selected aspects of cell, plant, invertebrate and mammalian life as a prerequisite to space flight experimentation. Gravitational biology, utilizing the centrifuge and clinostat, is singled out as one of the approaches required to unravel the variables associated with space flight in order to learn more about their biologic effects, either individually or in combination. (Author)

75. SCHAIRER, L.A., A.H. SPARROW and K.M. MARIMUTHU. 1970.
Radiobiological studies of plants orbited in BIOSATELLITE II.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VIII.**
North-Holland Publishing Company, Amsterdam. pp. 19-24.

The BIOSATELLITE II *Tradescantia* experiment probed the effects of the space environment on spontaneous and radiation-induced mutation rates and on cytological changes in *Tradescantia* clone 02. Thirty-two young flowering plants arranged in plastic housing with the roots immersed in nutrient solution were exposed to gamma radiation from an on-board ^{85}Sr source during the 2-day orbital flight. Unirradiated plants were flown in a package in the spacecraft behind a tungsten radiation shield and identical nonflight control packages (with and without irradiation) were maintained at the launch site. After retrieval of the spacecraft near Hawaii, samples of root tip, ovary and stamen tissues were collected. These and the intact plants were flown to the Brookhaven National Laboratory for observations on the following end points: somatic mutation, cell size, loss of reproductive integrity resulting in stunted stamen hairs, pollen grain mortality, frequency of micronuclei in pollen, disturbed mitotic spindle function and chromosome aberrations. Analysis of data on somatic mutation, cell size and chromosome aberration end points showed no significant differences between flight and nonflight samples. However, pollen abortion, frequency of micronuclei in pollen and loss of reproductive integrity (stamen hair stunting) showed increases associated with weightlessness in irradiated material. Root tip and microspore cells showed effects of disturbed mitotic spindle function in orbited plants both with and without irradiation. Clearly differences exist between flight and nonflight material and the significance and possible mechanisms for these effects are being studied in continuing nonflight tests. (Authors)

76. SHEN-MILLER, J. 1969.
Reciprocity in geotropic response and acceleration constraints of the biosatellites.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 93-94.

Georesponse acceleration thresholds for a 3-day exposure were determined on a 2-axis clinostat for oat seedlings. Values of approximately 10^{-3} g for the shoot and 10^{-4} g for the root indicate that the 10^{-5} g acceleration programmed for biosatellites is conservative. Clinostat determinations on the reciprocity rule (for threshold response, the product of the stimulation force and time is a constant) to determine if a constant could be calculated for gravity-compensated seedlings were successfully performed, and a constant of ca. 100gs at 28°C was derived suggesting that brief in-orbit accelerations, higher than originally planned, might be acceptable. (R.M.S.)

77. SLATER, J.V., B. BUCKHOLD and C.A. TOBIAS. 1968.
Effect on a flour beetle of irradiation during space flight.
BioScience *18*:595-597.

In BIOSATELLITE II, 720 *Tribolium* pupae between 19 and 27 hours old were orbited, half in the presence of ^{85}Sr and half shielded from it. Two-thirds of the pupae in each group had received a preirradiation dose of 1350r or 180 keV X-rays to bring them into a dose range similar to that which would result from additional inflight radiation. Identical Earth controls were maintained at 86°F. The percentages of wing abnormalities in the control group and the flight group are compared. A 50% increase in wing abnormalities was observed for the doubly irradiated flight group over the control group. The experiment was designed to study the effect of weightlessness alone and of gamma radiation combined with weightlessness on somatic wing development, germ cells, and the pupal period of the flour beetle, *Tribolium confusum*. (M.W.)

78. SLATER, J.V., B. BUCKHOLD and C.A. TOBIAS. 1968.
Synergism of X-irradiation and space flight in the flour beetle, *Tribolium confusum*.
Radiat. Res. *35*:501.

Pupae of *Tribolium confusum* aboard BIOSATELLITE II were of 4 experimental categories: nonirradiated; preflight irradiated; inflight irradiated; and preflight plus inflight irradiated. Comparison with ground controls indicated all flight samples had lengthened pupal periods possibly due to lowered temperatures during deorbit. The preflight plus inflight irradiated group showed a 50% increase in wing abnormalities and an increase in F_1 dominant lethality from females only. (R.M.S.)

79. SLATER, J.V., B. BUCKHOLD and C.A. TOBIAS. 1969.
Space flight enhancement of irradiation effects in the flour beetle, *Tribolium confusum*.
Radiat. Res. *39*:68-81.

The space environment and radiation on BIOSATELLITE II significantly enhanced two radiation effects in the developing flour beetle, *Tribolium confusum*. A developmental wing abnormality, appearing in adults following pupal irradiation, was increased to 44.8% in flight, compared with a control incidence of 29.9%. Similarly, dominant lethals of offspring of females irradiated in space increased significantly to 78% from 27% on the ground. Postflight ground tests indicate that weightlessness, not acceleration or vibration, was the contributing factor. The duration of the pupal stage was unaffected. All pupae were between 19 and 27 hours old at launch and were preirradiated with 1350r of 180 keV X-rays to place them into their sensitive dose range. Total irradiation received in space was approximately 950r. (Authors)

80. SPARROW, A.H., L.A. SCHAIRER and K.M. MARIMUTHU. 1968.
Genetic and cytologic studies of *Tradescantia* irradiated during orbital flight.
BioScience *18*:582-590.

During the BIOSATELLITE II flight, plants with roots immersed in nutrient were arranged in plastic modules so that the flower buds were exposed to approximately 218r and the roots from about 125 to 285r of gamma rays. Flight-control plants were located behind a tungsten shield and identical Earth-control packages (with and without irradiation) were maintained in the laboratory at the Cape Kennedy launch site. Somatic mutation rates, in general, did not change due to spacecraft orbital stresses, but in one case (stamen hair pink mutations) there was a statistically significant antagonistic effect on irradiated flight material for part of the scoring period. There was no general effect on mutation rates attributable to spacecraft factors and we cannot explain at present the one discrepancy. Incomplete analyses of the frequencies of various chromosomal aberrations suggest that significant differences between flight and Earth samples probably will not be found. Irradiated flight samples had higher rates of pollen abortion and stamen hair stunting, which suggest an enhanced effect between weightlessness and irradiation. Bud blasting, microspore death, disturbed spindle function, and other cytologic aberrations were observed more frequently in both flight samples than in both Earth samples. Weightlessness and/or other spacecraft environmental factors could be the cause of these effects. (Authors)

81. SPARROW, A.H., L.A. SCHAIRER and K.M. MARIMUTHU. 1968.
Genetic and cytological studies of *Tradescantia* irradiated during orbital flight.
Jap. J. Genet. *43*:470-471.

The Brookhaven experiment on board BIOSATELLITE II was designed to determine the effects of weightlessness and other spacecraft environmental conditions on spontaneous and radiation-induced mutation rates and on cytological changes in the higher plant, *Tradescantia* clone 02. During the two-day flight, 32 young plants were arranged in a plastic housing so that the flower buds were exposed to 218r of gamma rays and the roots, immersed in nutrient, were exposed to radiation levels from about 125 to 285r. Thirty-two flight control plants were flown in a package in the spacecraft behind a tungsten shield and identical ground control packages (with and without irradiation) were maintained at the Cape Kennedy launch site. Telemetered and on-board records were made of levels of vibration, shock, acceleration, etc., for use in subsequent flights and Earth-based tests. Immediately after retrieval of the spacecraft near Hawaii, samples of root tip, ovary and stamen tissues were collected. These and the intact plants were flown to Brookhaven for observations on the following end points: somatic mutation (blue to pink or colorless cells), cell size (giant and dwarf condition), irregular cell shape, loss of reproductive integrity (cell death and stunting in stamen hair growth), pollen grain mortality (early and late stages), abnormal cell divisions, and chromosome aberrations. Results to date indicate no effect of space flight factors on spontaneous levels of somatic mutation, pollen abortion, stamen hair cell death (stunting) and chromosome aberration. A difference was noted, however, in the normal development and function of the mitotic spindle mechanism in microspores and root tip cells. Interaction of ionizing radiation with space flight factors was expressed in various patterns. Established Earth-based radiation-induced somatic mutation rates in general were unaffected by flight factors with the exception of the pink stamen hair cell mutation which exhibited an antagonistic response to flight factors. This discrepancy is at present unexplained. Enhanced interactions between radiation and space flight factors were indicated by an increase in pollen abortion, stamen hair stunting and chromosome aberrations (particularly chromosome exchanges). These observations suggest increased injury during the more sensitive stages of meiosis and mitosis. Clearly differences exist between Earth and flight samples both with and without irradiation. (Authors)

82. SPARROW, A.H., L.A. SCHAIRER and K.M. MARIMUTHU. 1968.
Radiobiological studies of *Tradescantia* plants orbited in BIOSATELLITE II.
Radiat. Res. *35*:502.

The BIOSATELLITE II *Tradescantia* experiment was designed to determine the effects of weightlessness and other biosatellite environmental conditions on spontaneous and radiation-induced mutation rates and on cytological changes in *Tradescantia* clone 02. Thirty-two young plants, heterozygous for flower color, were placed in a plastic housing with the roots immersed in nutrient. The inflorescences were expected to receive a uniform total gamma exposure of about 218r during the flight. The 32 flight control plants were flown in the spacecraft behind a tungsten shield. Material was prepared at and launched from Cape Kennedy. Identical packages (with and without radiation) were maintained at the launch site. Immediately after retrieval of the spacecraft near Hawaii, root tip, ovary, and stamen tissues were fixed. These and the intact plants were flown to Brookhaven for observations on the following end points: somatic mutation (blue to pink or colorless cells), cell size (giant and dwarf condition), irregular cell shape, loss of reproductive integrity, pollen abortion, microspore death, disturbed spindle, and chromosome aberrations. Although results obtained for most of these end points so far show little, if any, modification attributes to weightlessness, it seems probable that some differences will be found when data analyses are completed. Data from uncompleted postflight ground-based control experiments are required for the final interpretation of these BIOSATELLITE II flight data. (Authors)

83. SPARROW, A.H., L.A. SCHAIRER and K.M. MARIMUTHU. 1970.
Tradescantia experiment in BIOSATELLITE II.
In: Proceedings of the Symposium on Radiation Biology and Space.
International Congress of Radiation Research, Evian, France. [In Press]

A modified frequency of several spontaneously occurring or radiation-induced effects in *Tradescantia* plants was attributed to orbital flight environments of BIOSATELLITE II. These effects are rather small but significant and appear to be related to effects on normal cell division and cell survival. High rates of pollen abortion, micronuclei, and stamen hair stunting are unique to the irradiated, orbited sample and reflect an enhanced interaction between radiation and weightlessness. Nuclear misorientation and flower production were increased significantly in both irradiated and nonirradiated flight

samples. Although these effects have been attributed to weightlessness alone, they may conceivably be due to weightlessness preceded and/or followed by vibration or other dynamic factors associated with orbital flight. Several of the effects studied either showed no modification attributable to the flight environment or showed a modification not thought to be caused by weightlessness. (Authors)

84. SPARROW, A.H., L.A. SCHAIRER and K.M. MARIMUTHU. 1971.
Radiobiologic studies of *Tradescantia* plants orbited in BIOSATELLITE II.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

85. THIMANN, K.V. 1968.
BIOSATELLITE II experiments: Preliminary results.
Proc. Nat. Acad. Sci. *60*:347-361.

The BIOSATELLITE II mission is briefly described. All experiments aboard and the preliminary results from each are outlined using several photos, charts, and graphs to reinforce the text. The author indicates that only one of two major questions was well answered by results obtained from the biosatellite. In his opinion, orbiting does not induce changes which are not simulated by gravity balancing devices on the ground. The second question, concerning relative roles of weightlessness and/or vibration in combination with radiation to produce an enhancement of genetic alterations, was unclearly answered without establishment of causal relationship. (R.M.S.)

86. TOBIAS, C.A., B. BUCKHOLD and J.V. SLATER. 1971.
Some effects of space flight on the flour beetle *Tribolium confusum*.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

87. U.S. CONGRESS, HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS. 1970.
The Future of The Bioscience Program. Hearings, 91st Congress, 1st Session.
U.S. Government Printing Office, Washington, D.C. 244 pages.

This transcript represents hearings held at the request of the Committee on Science and Astronautics for reviewing the status and future of the Bioscience Program of NASA. The concern of the committee repeatedly expressed was whether or not development of 28- and 56-day space missions is appropriate, based solely on experience gained from a single 14-day Gemini mission. Contributory to the concern was the BIOSATELLITE III flight which was terminated during the 9th day in orbit due to the decline of the monkey passenger who died shortly thereafter resulting, at least in part, from the effects of the space environment. The committee questioned the deletion of a second primate flight from NASA's program and the absence of a continuing bioscience program. A summary of the history and future of the space biology program, objectives of the BIOSATELLITE III mission and the observations, implications and relationships to manned flight missions were presented by Dr. John E. Naugle and Dr. Orr E. Reynolds. The spacecraft itself and the flight operation were discussed by Mr. John W. Dyer. Techniques and data from the experiment were presented by Dr. W. Ross Adey, who makes a strong recommendation for a more complex bioscience program. Dr. Nello Pace emphasized the unique value of the space environment as a physiological tool, and the necessity for a vigorous research program. Cardiovascular function data from BIOSATELLITE III were given by Dr. J. P. Meehan. A joint statement by Dr. J. W. Humphreys and Dr. Charles A. Berry presented the view that animal experiments were not necessarily precursors to manned space flight. The range and types of biomedical data from 5,000 man-hours of space travel was indicated in support of this view. The statement of Dr. James V. Warren took the position that a strong integrated program of animal research and human medicine should be developed within NASA. The need for manned space exploration was emphasized by Dr. Lamont C. Cole. He also mentioned the value of space for the study of periodic behavior patterns, and argued against the use of man as the sole test species of the effects of the space environment. The concept of concurrent use of animals and man in investigations of the effects of the

space environment appeared also in a statement by Dr. Loren D. Carlson. He indicated a desire for further subhuman primate space experiments. The final witness before the hearing was Dr. Donald Farner who gave analysis of the group participating in the space biology summer study at Santa Cruz in July 1969. His impression was that opinion was generally in favor of the space bioscience program. (R.M.S.)

88. von BORSTEL, R.C. et al. 1968.
Experiments with *Habrobracon* and *Tribolium* on BIOSATELLITE II.
Jap. J. Genet. *63*:464.

The most distinguishing genetic feature of *Habrobracon* is that, by virtue of the haploid males, the entire genome can be revealed in one or two generations. *Tribolium* offers threshold systems where small enhancing or antagonistic responses of the environment in association with radiation induce a large, easily detectable effect. Both genetic and somatic systems in *Habrobracon* and *Tribolium* were examined after the insects had been carried in BIOSATELLITE II. Under a field of radiation, space flight conditions were responsible for an enhancement of total dominant and recessive lethality in metaphase I oocytes and early prophase I oocytes of *Habrobracon*, as well as an enhancement of dominant lethality in oogonia of *Tribolium*. On the other hand, the irradiated oogonia of *Habrobracon* apparently showed much less damage than ground-based controls. The sperm of *Habrobracon* had an increased recessive lethal frequency in the unirradiated compartment; neither *Habrobracon* sperm nor *Tribolium* spermatogonia showed any change from the ground-based controls when irradiated. The somatic studies of *Tribolium* disclosed an enhancing effect of space flight conditions and radiation when wing abnormalities of developing pupae were criterion. The life span of *Habrobracon* females carried on the biosatellite was significantly longer than those in ground-based controls. (Authors)

89. von BORSTEL, R.C. et al. 1968.
The *Habrobracon* experiment in the BIOSATELLITE II spacecraft.
Radiat. Res. *35*:501.

Two hundred seventy-eight males of the lemon strain of *Habrobracon juglandis* Ashmead and 280 virgins heterozygous for lemon, cantaloup, and honey were orbited in the BIOSATELLITE II spacecraft. The nominal protracted exposures to be given were 4000r, 2000r, 1000r, 500r, and 0r. In addition, a group X-irradiated with a brief exposure of 2000r was placed in the 0r package. None of the nominal exposures (excepting 0r) was achieved, principally because the spacecraft was recovered after 30 orbits instead of the schedule 46 orbits. *Habrobracon* also were placed in ground-based control setups which rigorously followed the radiation, temperature, and time-of-flight profiles of the spacecraft. A large synergistic effect of space flight with the concurrent or previous irradiation was found on oocytes that were in the first meiotic metaphase of meiosis when total dominant and recessive lethal mutation frequencies were criterion. Antagonistic effects of space flight with concurrent or previous irradiation were found on transitional and primitive oogonia when cell killing was the criterion. There was no significant effect of space flight on mutation frequencies induced in sperm when the radiation was given either previous to or concurrent with the flight. (Authors)

90. von BORSTEL, R.C. et al. 1968.
Mutational response of *Habrobracon* in the BIOSATELLITE II experiment.
BioScience *18*:598-601.

When dominant lethality in *Habrobracon* sperm was the criterion, no interaction effects of γ-radiation and space flight were found. When dominant and recessive lethality in *Habrobracon* oocytes in the first meiotic metaphase was the criterion, a marked enhancing effect of radiation in space flight was seen. The late prophase I oocytes were insensitive, but the small prophase I oocytes were similar to metaphase I oocytes in exhibiting an enhancing effect of radiation during space flight. When killing of transitional and primitive oogonia was measured by fecundity, a marked antagonistic effect of radiation by space flight was observed. The enhancing and antagonistic effects were observed whether the *Habrobracon* were irradiated either before or during the flight, although the effect was greater in those *Habrobracon* irradiated during the flight. (Authors)

91. von BORSTEL, R.C. et al. 1969.
Mutational responses of insects in the BIOSATELLITE II experiment.
In: W. Vishniac and F.G. Favorite, eds. Life Sciences and Space Research VII.
North-Holland Publishing Company, Amsterdam. pp. 70-76.

Genetic effects associated with space flight include mutation induction by the space flight itself and enhancements or antagonisms of radiation-induced mutations. The conditions of space flight vary in mutagenic effectiveness from no response at all to responses nine times greater than that found in ground-based controls. The test systems follow the sensitivity pattern from spermatogonial translocations to oogonial and oocyte nondisjunction to recessive lethality of stages in spermatogenesis to dominant lethality of stages in spermatogenesis. Large enhancing and antagonistic effects of space flight in conjunction with radiation were observed in the BIOSATELLITE II experiment. The most surprising one was the elimination of the effect of 2500r by space flight in *Habrobracon* oogonia where the effects of 500r normally can be easily observed. Two sets of parameters are considered in attempts to explain the responses; the nature of the biological targets, and the particular conditions of space flight that are responsible for the effects. (Authors)

92. von BORSTEL, R.C. et al. 1970.
Biological responses of *Habrobracon* to space flight.
In: W. Vishniac and F.G. Favorite, eds. Life Sciences and Space Research VIII.
North-Holland Publishing Company, Amsterdam. pp. 6-11.

Since the interaction of the parasitic wasp *Habrobracon* with the space environment could not be prejudged, we decided to test approximately 30 different parameters of a genetic, mutational, biochemical, behavioral, and physiological character in the one space flight we had at our disposal. These parameters were examined at six different exposures of gamma radiation (including 0 dose) in flight, resulting in about 180 different end points in all. The most profound effects of space flight in conjunction with radiation were decreased hatchability and enhanced fecundity of eggs exposed to space flight at different stages of oogenesis. The interpretation we favor is that these two end points are reflections of chromosomal nondisjunction in the former case and inhibition of cell division in the latter. Our most comprehensive study of mutagenesis was on sperm, where dominant lethality, recessive lethality, translocations, and visible mutations were assayed; the only effect found was a threefold enhancement of the recessive lethal mutation frequency on the nonirradiated sperm in the orbited *Habrobracon* males. Behavioral and biochemical differences were found. Mating activity of orbited males was severely disrupted and xanthine dehydrogenase activity was sharply decreased in the irradiated flight animals, an unexpected observation. Postflight experiments were like the ground-based control experiments in all aspects but one. Under conditions of vibration similar to those encountered during the launch and reentry, the mutation frequency in the sperm increased by a factor of three over that of the nonvibrated control. (Authors)

93. von BORSTEL, R.C. et al. 1971.
Mutation responses of *Habrobracon* in BIOSATELLITE II.
In: J.F. Saunders, ed. The Experiments of BIOSATELLITE II.
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

94. WILSON, C.A. 1968.
The BIOSATELLITE II mission.
BioScience *18*:549-554.

The coordination and development of the hardware and procedure which were brought together for the highly successful BIOSATELLITE II mission are described. The author also discusses briefly the recovery of the experimental package and the analyses of both biological and engineering aspects of the mission. Among the latter were control systems which did not function perfectly, the improved collection of internal environment data by tape recorder, and the demonstration of second-burn capability of the DELTA booster. (R.M.S.)

95. YOUNG, R.S. 1968.
Biological experiments in space.
Space Sci. Rev. *8*:665-689.

Effects of weightlessness, increased gravitational fields, and radiation on biological systems at the organismal, cellular and subcellular levels, observed in biosatellite experiments, are reported in detail. Studies of the hazards of space flight from the point of view of manned flight are also reported. (M.W.)

96. YOUNG, R.S. and J.W. TREMOR. 1968.
The effect of weightlessness on the dividing egg of *Rana pipiens*.
BioScience *18*:609-615.

Evidence presented shows the fertilized egg of *Rana pipiens* to divide, differentiate, and develop normally when exposed to weightlessness over 2 days during BIOSATELLITE II, with initiation of exposure at the mid-2-cell stage. Rate of development was also unaffected. Where differences in developmental stage did occur, they were attributed to temperature differences and/or time of observation. Abnormalities in the embryos included asymmetric cleavage planes, localized cytolysis, edema, exogastrulation, etc. However, there were no differences in the types of abnormalities between the flight and control eggs. Similarly, there were no ultrastructural differences in the flight and control embryos in terms of the number and width of cristae in mitochondria, yolk platelets, nuclei and cell membranes. It is thought that earlier exposure of the egg to weightlessness would complement the finding of Earth-based studies in which gravity is implicated as a determiner of normal development. (M.W.)

97. YOUNG, R.S. et al. 1971.
The effects of weightlessness of the dividing eggs of *Rana pipiens*.
In: J.F. Saunders, ed. **The Experiments of BIOSATELLITE II.**
National Aeronautics and Space Administration, NASA SP-204, Washington, D.C. [In Press]

See #74 for editor's abstract.

SECTION II. BIOSATELLITE PREFLIGHT STUDIES

98. ADEY, W.R. 1960.
Instrumentation of nervous system for studies of behavior and performance in space flight.
In: IRE Transactions, Fifth National Symposium on Space Electronics and Telemetry.
Institute of Radio Engineers, Inc., New York. Sect. 6-2, pp. 1-13.

Recordings of evoked and spontaneous brain activity provide an excellent measure of the state of sleep and wakefulness of the subject. Such recordings provide a clear indicator of an animal's condition in circumstances in which mere failure to perform a trained task can give no indication of the basic cause. These recordings provide more information concerning performance capacity than does an EKG. Recordings of activity in the temporal lobe, implicated in memory functions, social behavior, and emotional and sexual responses, are of particular importance. Electrodes can be chronically implanted, and recordings made from freely moving animals. The temporal areas of primary interest are the hippocampus and amygdala. The resulting data are usually analyzed by auto- and cross-correlation computer techniques, which show some aspects of the EEG rhythmicity. The results have demonstrated consistent patterns of phase relations between different hippocampal regions as the animal approaches reward or becomes better trained on a task. Self-stimulation methods may also prove useful in clarifying the complex relationships between brain and behavior. (M.W.)

99. ADEY, W.R., D.O. WALTER and C.E. HENDRIX. 1961.
Computer techniques in correlation and spectral analyses of cerebral slow waves during discriminative behavior.
Exp. Neurol. *3*:501-524.

Comprehensive cross-spectral analysis of EEG recordings from different areas of the hippocampal arch of cats trained in T-maze and delayed response tests has revealed highly consistent patterns with a dominant frequency in a narrow range of 6 cps during approach on a well learned task. A wide spectrum with a dominant 3-4 cps frequency during pre-approach periods and distinct differences in phase patterns during incorrect responses was seen. The possible role of wave patterns in integration and transfer of information is discussed. (R.M.S.)

100. ADEY, W.R. et al. 1961.
EEG records from cortical and deep brain structures during centrifugal and vibrational acceleration in cats and monkeys.
IRE Trans. Biomed. Electron. *BME-8*:182-188.

Electroencephalographic records have been taken from deep regions of the brains of cats and monkeys with chronically implanted electrodes during centrifugal and shaking accelerations comparable to booster forces. Histological and X-ray controls have indicated that displacement of the electrodes does not occur, and that damage to brain tissue is comparable with nonaccelerated animals. A transistorized EEG amplifier suitable for recording in satellite biopack environments has been developed. In centrifuge tests, transverse accelerations up to 8g were associated with rhythmic "arousal" patterns of slow waves in hippocampal regions of the temporal lobe during increasing or decreasing acceleration. Longitudinal accelerations between 5 and 6g produced blackouts after 30 to 40 seconds, with flattening of EEG records, and frequently with induction of epileptic seizure in temporal-lobe leads. Shaking tests suggested that vibrational acceleration may be associated with the intermittent "driving" of the cerebral rhythms, in a fashion resembling photic driving, at shaking rates from 11 to 15 cps, and from 22 to 30 cps. (Authors)

101. ADEY, W.R. and J.D. FRENCH. 1962.
On the value of electroencephalographic recording in man and animals in space flight.
In: Proceedings of the Twenty-Second International Congress of Physiological Sciences, Supplementary Vol. I.
International Union of Physiological Sciences, Leiden. pp. 104-106.

Studies of the feasibility of recording electrical brain activity in animals and man, under simulated stresses of booster forces and reentry, and the patterns of brain activity, during confinement and reduced sensory stimulation resembling space flight conditions, are reviewed. Electrodes have been implanted in monkeys and chimps in surface and deep structures of the temporal lobe (particularly

the amygdala and hippocampus) and in the thalamus and midbrain reticular formation. Electrical rhythms in these areas reflect changing states of consciousness, attentiveness, and discriminative performance during learning. Characteristic changes, which impair cerebral circulation, occur in EEGs during centrifugation. At accelerations of 5-7g for 30 seconds or more in a rostro-caudal direction, the amygdaloid retains residual bursts of fast waves even after other areas have flattened. If the acceleration to 6g occurs gradually the flattening process may be interrupted by high amplitude seizure discharges, initiated in the hippocampus, but spreading to thalamic and later to cerebral cortical zones. Shaking of the whole body produces intermittent driving of the brain wave rhythms from 5 to 30 c/sec at peak accelerations up to 3.5g. Simulation of weightlessness has been accomplished with the use of hallucinogens (e.g., LSD) under restricted sensory and space conditions; seizure discharges in the hippocampus resulted, and spread to cortical structures. (M.W.)

102. ADEY, W.R. 1963.
Aspects of brain physiology in the space environment.
In: M.A.B. Brazier, ed. **Brain Function.**
University of California Press, Los Angeles. pp. 321-345.

In regard to the implications of brain mechanisms regulating cortical excitability in a space environment, an area of primary interest is the effect of weightlessness on sleep cycling. Animals in a buoyant condition (e.g. dolphins) appear to sleep very little, as do monkeys raised from birth in a state of great sensory reduction. When a modifying sensory input, LSD, is given to cats with reduced sensory input (i.e., kept in the dark), a "spontaneous" seizure activity, which disappears when the animal is brought into the light, is produced. Another area of concern is effects of irradiation on brain functions, particularly when applied to the temporal lobe. With a dose of 250 kV X-rays, 200-400r, spikes appear in the system and progressively increase with doses up to 400r. However, there is no disruption of learned behavior during these spike discharges. A third area of interest is the feasibility of recording EEG's during orbital flight with electrodes implanted in the hippocampus, piriform cortex, amygdaloid complex, visual cortex, reticular system, and the sensorimotor cortex. The animal was then centrifuged up to 10g in several planes, and the resulting records taken before and after these episodes of severe physical stress were not significantly different. (M.W.)

103. ADEY, W.R. et al. 1963.
EEG in simulated stresses of space flight with special reference to problems of vibration.
Electroenceph. Clin. Neurophysiol. *15*:305-320.

The effects of shaking on the electrical brain activity as recorded in cortical and subcortical structures of four pig-tailed macaques (*Macaca nemestrina*) are described. Shaking was performed over a continuous spectrum from 5-40 c/sec, at a peak acceleration of 2g over the greater part of the spectrum. Driving of brain rhythms at the shaking frequency was noted in the midbrain reticular formation, the nucleus centrum medianum, the visual cortex and the hippocampal system. An essentially different distribution of driving was produced by photic stimulation. Control procedures indicated that this rhythmic driving was abolished or greatly reduced by pentobarbital anesthesia in both cortical and subcortical structures. It did not arise through sway artifacts in recording leads nor was it due to magnetic flux leakage in the vicinity of the shaking transducer. The driving was maximal in the frequency range from 9-15 c/sec. At frequencies from 15-20 c/sec, evidence was found of driving at half the shaking frequency. The driving was frequently dissociated in simultaneous records from adjacent brain structures, and from leads in symmetric bilateral placements. Concurrent behavioral performance in an oddity-discrimination test indicated an increase in errors, lack of attention and longer latency of responses at shaking frequencies around 11 c/sec, associated with maximal rhythmic EEG driving. An isolated instance of seizure induction during shaking under pentobarbital anesthesia is described. Special requirements for EEG recording in manned space flight are discussed. (Authors)

104. ADEY, W.R. 1963.
Potential for telemetry in the recording of brain waves from animals and men exposed to the stresses of space flight.
In: L. Slater, ed. **Bio-Telemetry.**
Pergamon Press, New York. pp. 289-302.

Studies conducted during the past three years to test the feasibility of the telemetry of EEG's from animals and men in space flight, including the booster and reentry phases, are reported. A number of implantation techniques have been tried, using rigid or unsupported electrodes. The temporal lobe, which appears to be most sensitive to behavioral changes, has been the primary site studied. An amplifier with a complete EEG channel with a gain of about 40,000 and with all thermally sensitive components in a block of magnesium alloy has been developed and has proved rugged and reliable. A microminiaturized amplifier in an electrode attached to the scalp has also been used. For centrifuge experiments, a behavioral test panel was built to test discrimination ability. It consisted of three boxes projecting symbols three at a time on small screens; the animal was required to select the odd one of the three to receive a food reward. Telemetry problems were approached through the use of standard IRIG subcarrier oscillators, with as many as 28 channels of data on two tracks. Monkeys were tested on a discriminative task during centrifuging through the full Atlas booster profile while confined in a simulated capsule for 14-day simulated orbital flights. During increasing longitudinal acceleration to 8g, there is a blackout, loss of consciousness, and a flattening of the record with spike-like discharges in epileptic form from deep in the temporal lobe. The effects of shaking consist of a driving of the brain wave rhythms at the rate of the shaker, especially around 10 c/sec. (M.W.)

105. ADEY, W.R. 1964.
Effects of gravity on the functions of the central nervous system.
In: M. Florkin and A. Dollfus, eds. **Life Sciences and Space Research II.**
North-Holland Publishing Company, Amsterdam. pp. 267-286.

The sensitivity of the mammalian nervous system to gravitational influences involves both direct and indirect factors. Gradual loss of cerebral circulation with increasing acceleration beyond 5g has been shown to evoke changes in patterns of brain electrical activity, with epileptiform discharges triggered primarily in the hippocampal system of the temporal lobe, and spreading into other brain systems. The relationship of these structures to judgment and discriminative functions is discussed. Complete loss of cerebral circulation is associated with electrical silence in the brain. The possible effects of weightlessness on intracranial fluid distribution are reviewed. Tests of vibrational stimuli in the monkey have disclosed "driving" of electrical brain rhythms at the shaking frequency, particularly in the range from 11 to 15 c/sec. These effects are unrelated to photic stimulation, and are abolished by anesthesia or death. Tests of discriminative capability at frequencies producing maximum driving have shown increased response latencies and increased errors. The neurophysiological basis for adaptive phenomena in recurrent vestibular stimulation has been found to reside partly in the vestibular nuclei of the medulla, and not to require integrity of connections with higher vestibular centers. The potentiation of responsiveness to vestibular stimulation in the weightless state has been shown to have a basis in the exaggerated responsiveness of medullary vestibular centers following loss of proprioceptive influxes from the spinal cord. The possible contribution of weightlessness to anomalous psychophysiological functions is reviewed. This area presents a major challenge in experimental design, and may require evaluation of such phenomena as distortion of the body image, modified sleep patterns and changes in optimal sleep-work cycles. (Author)

106. ADEY, W.R. 1965.
Biosatellite performance simulation.
In: L.D. Proctor and W.R. Adey, eds. **Symposium on the Analysis of Central Nervous System and Cardiovascular Data Using Computer Methods.**
National Aeronautics and Space Administration, NASA SP-72, Washington, D.C. pp. 357-384.

Hardware and techniques designed for EEG monitoring of cardiovascular functions, task performance, and the simulation testing of these tools in preparation for biosatellite use on a monkey are discussed. Histological evidence is discussed with the conclusion that the implant technique for EEG recording is adequate. The task performances described are delayed matching-to-sample and a test of eye-hand coordination with rotating discs. Briefly mentioned are electro-oculographic and electromyographic recording devices, a pneumogram, core and cerebral temperature, cerebral O_2 tension taking, and urine volume and pH measures. Sensing mechanisms under test for cardiovascular measures are catheterization of right heart, carotid artery or aorta, and both femoral arteries, and an implanted transducer in a silicon rubber bag. The results of shaking and acceleration simulations on EKG and EEG are reproduced and discussed after a short description of the simulator employed. The need for

further observations on the effect of environmental change on urine content and volume, and the need for urine fractionation as a daily experiment are stressed. Some techniques for computer analysis of data are mentioned. (R.M.S.)

107. ADEY, W.R. 1966.
Central nervous, cardiovascular, and visuomotor studies relating to spatial orientation in a 30-day primate flight.
In: Second Symposium on the Role of the Vestibular Organs in Space Exploration.
National Aeronautics and Space Administration, NASA SP-115, Washington, D.C. pp. 293-307.

The central nervous mechanisms underlying orienting and visual discriminative functions during a 30-day primate flight are analyzed in terms of the interrelations of vestibular and optic sensory influxes with corticodiencephalic and limbic processes as essential substrates for this behavior. Techniques for recording central nervous functions were developed for the flight of Biosatellite D. These include electro-oculographic and electromyographic processes, autonomic responses (GSR, impedance pneumogram, EKG), cardiovascular data (pressures in femoral and carotid arteries, right atrium, and left ventricle), behavioral tasks involving matching-to-sample and an eye-hand coordination, and urine and feces analyses. The various systems necessary for this experiment are a centrally located couch support for the *Macaca nemestrina* monkey, with the animal facing forward; an effective suit restraint; a behavioral test panel located in front of the animal; a pellet feeder combined with reward and ad libitum methods, and water provided from the fuel cell power system. Data will be handled through extensive spectral analyses by digital computation and the calculation of auto- and cross-spectral densities, including phase angles, shared amplitudes, and coherence function. (M.W.)

108. ADEY, W.R. 1967.
Hippocampal states and functional relations with cortico-subcortical systems in attention and learning.
In: R. Adey and T. Tokizane, eds. Structure and Function of the Limbic System.
Elsevier Publishing Company, Amsterdam. pp. 228-245.

Some of the functional aspects of the hippocampus in regard to learning and perceptual behavior and the relations with various cortical and subcortical systems are described. The intrinsic electrical activity of this structure is emphasized. During the performance of behavioral tasks with alerting, orienting, and discriminating stimuli, changes in the tissue states of the hippocampus were studied with impedance measurements. The relationships between the response of various areas to these stimuli at different stages of training, cue reversals, and retraining were investigated. Resulting data suggest that the evoked impedance changes are related to a process of information storage in the hippocampus rather than to nonspecific total tissue activity. (M.W.)

109. ADEY, W.R. 1967.
Intrinsic organization of cerebral tissue in altering, orienting and discriminative responses.
In: G.C. Quarton, T. Melnechuk and F.O. Schmitt, eds. The Neurosciences: A Study Program.
Rockefeller University Press, New York. pp. 615-633.

This review considers the gamut of neural organization, ranging from subcellular events in the genesis of intracellular waves, to the patterns in scalp EEG records characterizing a population of human subjects in states of focused attention and visual discrimination. A tricompartmental model of cerebral tissue is described, with neuronal, neuroglial and extracellular divisions. The role of macromolecular systems at the neuronal surface and in the intercellular fluid is considered. Evidence is presented that mucoproteins and mucopolysaccharides may be responsible for net fixed charges at the cell surface, and may thus play a role in ionic fluxes across the membrane. Divalent cations, such as calcium, may modify these macromolecular configurations. Impedance changes in cerebral tissue accompanying alerting, orienting and discriminative responses are described, with emphasis on their regional distribution, and relationship to levels of learning. (Author)

110. ADEY, W.R., R.T. KADO and D.O. WALTER. 1967.
Results of electroencephalographic examinations under the influence of vibration and centrifuging in the monkey.
In: L. Widen, ed. Recent Advances in Clinical Neurophysiology. Electroencephalography and Clinical Neurophysiology, Supplement 25.
Elsevier Publishing Company, Amsterdam. pp. 227-245.

The effects of whole body vibration over the range from 5 to 40 c/sec on cortical and subcortical EEG activity have been tested in the intact monkey (*Macaca nemestrina*) and after bilateral section of the vestibular nerves. Extensive computed analyses were made of auto- and cross-spectra, including calculations of shared amplitudes, phase angles and coherence. Induced EEG rhythmicity occurring at certain frequencies of whole body vibration had the characteristics of a physiological "driving," and appears distinguishable from superficially similar phenomena of artifactual origin. Autospectral density plots showed little or no evidence of EEG driving below 9 c/sec, despite powerful head movements. Driving at the shaking rate was frequency selective and maximal in the range 10-15 c/sec. However, in many instances, maximum EEG energy peaks occurred at other than shaking frequencies, and without harmonic relationship to shaking frequencies. Coherence (linear predictability) was high between cortical and subcortical leads at EEG frequencies unrelated to concurrent shaking frequencies, and absent from baseline records before or after shaking. This may imply aspects of cerebral system organization with ephemeral sharing of activity elicited by the vibratory volleys. Coherence between head and table accelerometers and cortical and subcortical leads were below significant levels at fundamental driving frequencies below 11 c/sec, although significant coherence peaks appeared at other EEG frequencies. Shaking in the range 11-17 c/sec produced many coherent relationships at fundamental driving frequencies, and at harmonically related and unrelated EEG frequencies. Bilateral section of the eighth nerve did not abolish this driving. Physiological mechanisms which might underlie this driving are discussed, including the role of abdominal, thoracic and cervical tissues. Brief centrifuging to high G levels was followed by paroxysmal cortical and subcortical slow wave activity, associated with missed cardiac beats. (Authors)

111. ADEY, W.R. 1968.
Aspects of cerebral organization: Information storage and recall.
In: W.C. Corning and M. Balaban, eds. The Mind: Biological Approaches to Its Functions.
John Wiley & Sons, New York. pp. 69-100.

The author describes a tricompartmental model of brain tissue with neuronal, neuroglial and extracellular elements, each of which is important to his theory of learning and memory. The discussion includes the electrical activity of the brain. The author outlines techniques and results of recording the dual and essentially independent activities of a single brain cell, those of wave and spike production. The complex behavior of a single cell is illustrated by a series of recordings made during the Pavlovian conditioning of a single cat dorsal thalamic neuron. It is noted that single cell behavior, though a component of wave behavior, may not reflect excitation or inhibition of the surrounding tissue as a whole. The author describes a technique for the comparison of learned behavior performance with the averaged wave activity of large tissue areas. The analysis of this wave activity has given indications of memory traces laid down throughout the brain system modulated by a temporal pacemaker. A number of computer analysis techniques are discussed, and computer modulated brain wave plots are reproduced. Information is carried on the inflection and frequency of the wave activity and the formation and recall of a memory trace are shown to be due to the wave trains, retrieval thus being a statistical "best-fit" basis. Having established the importance of frequency changes with these results and drug studies, the author describes a technique for measuring brain impedance which has detected changes appropriate to concurrent behavior, i.e., a drop in impedance in response to alerting stimuli. These changes may be neuroglial or extracellular. It is speculative that the location of memory traces is at the neuronal-neuroglial interface. (R.M.S.)

112. ADEY, W.R. 1969.
Neural information processing; windows without and the citadel within.
In: L.D. Proctor, ed. Cybernetics of the Central Nervous System.
Little, Brown and Company, Boston. pp. 5-27.

The author considers some of the differences between the living brain and the typical artificial processor within the general context of neural information processing. In discussing some of the primary functions involved in nervous processing, the shift in coding patterns at various levels in the central nervous system and the establishment of excitability thresholds in sensory neurons are emphasized. Each individual brain cell is viewed as a component in a multicompartmental neuronal system, and the patterns of electrical activity and membrane phenomena are described. Some of the relationships between EEG and behavior are analyzed and some unifying hypotheses are suggested. (M.W.)

113. ADEY, W.R. 1969.
A step ahead of the astronauts.
Mod. Vet. Prac. *50*:35-42.

Definite physiological changes occur during the prolonged weightlessness of an extended space flight, and although some of them are predictable, others must be determined by experimentation with subhuman primates. Preparation for the BIOSATELLITE III flight included collection of baseline data by monitoring: brain temperature, arterial and venous blood pressure, EKG, eye movements, heart rate, respiratory rate, sleep-wake cycles, bone demineralization, and muscle atrophy (through chemical analysis of urinary creatine, creatinine, and calcium). A new procedure was introduced for the care, feeding, and training of a colony of subhuman primates involving computer analysis. The candidates for the flight underwent two types of training: short-term memory and discrimination between visual symbols, and muscle-eye coordination. Baseline EEG data was recorded during training and compared with records obtained during flight. (M.W.)

114. ANONYMOUS. 1965.
The NASA Biosatellite Program.
In: Significant Achievements in Space Bioscience 1958-1964.
National Aeronautics and Space Administration, NASA SP-92, Washington, D.C. pp. 72-75.

The concept of the biosatellite is described, and a general outline of the 20 experiments planned for 6 orbiting vehicles is given. The launch hardware for the entire series and its testing for resistance to launch and recovery stresses is briefly described. (R.M.S.)

115. ANONYMOUS. 1969.
To fill the gaps in space medicine.
Sci. News *95*:569-570.

This nontechnical news release outlines the type of data to be collected from the BIOSATELLITE III experiments and indicates some of the techniques used in the exhaustive instrumentation of the macaque monkey subject. Sensors monitor brain function, eye movement, blood pressure and urine composition. Additionally, cell loss, changes in red cells and body fluids, solid and liquid waste alterations, skeletal changes, and sperm maturation changes are all mentioned as laboratory observations to be carried out in preflight and postflight studies. (R.M.S.)

116. APPLIED PHYSICS LAB., JOHNS HOPKINS UNIVERSITY. 1968.
Extended Duration, Recoverable Primate Satellite.
National Aeronautics and Space Administration, NASA-CR-926, Washington, D.C. 147 pages.

The results are presented of a brief engineering study of a proposed six-month orbital physiological experiment generally referred to as the Primate Orbital Experiment. In this proposed Apollo Application experiment, two live squirrel monkeys would be placed into a low Earth orbit, then recovered alive approximately six months later, for examination on the ground. This study includes all spacecraft systems, life support, and instrumentation for an experiment package which could be transported into orbit by an Apollo spacecraft and function autonomously until picked up six months later through rendezvous with a second Apollo spacecraft. Presented are approaches to possible ways of integrating the animal-carrying satellite with Apollo during launch, and feasible life support and instrumentation techniques to maintain the animals alive in orbit for six months. Techniques for retrieval are suggested. (Author)

117. BATINI, C. et al. 1967.
Effect of interhemispheric transection on the EEG patterns in sleep and wakefulness in monkeys.
Electroenceph. Clin. Neurophysiol. *22*:101-112.

The role of the interhemispheric commissural pathways in the synchronization of cerebral electrical activity has been studied in *Macaca nemestrina*. Five animals were prepared with midsagittal sections of the commissures and brain stem extending caudally to various levels. Electrodes were implanted for recording from cortical and deep brain structures. Electrodes were also implanted in three intact animals for control. During transition from the fully alert to the drowsy state, the onset of EEG slowing and rhythmical patterns appeared simultaneously in both hemispheres, whether the animals were hemisectioned or not. Shifts in behavioral states from vigilance to sleep or arousal, with corresponding changes in the EEG from fast, low voltage to slow waves and vice versa, are characterized in both groups by a simultaneous bilateral symmetry of these cortical EEG events. The ratio of sleep to wakefulness was sharply reduced in the hemisectioned animals. The proportion of time spent in activated sleep was related to the level of the brain stem lesion. (M.W.)

118. BERKHOUT, J., W.R. ADEY and E. CAMPEAU. 1969.
Simian EEG activity related to problem solving during a simulated space flight.
Brain Res. *13*:140-145.

In order to establish physiological base levels for a 30-day orbital experiment, a monkey (*Macaca nemestrina*) was studied while isolated in a grounded space capsule for thirty days. A 4-symbol delayed-watching problem had been selected to monitor the animal's integrity of mentation during orbital flight, and the monkey subject was trained to perform this task prior to isolation in the capsule. Physiological instrumentation included implantation of 6 deep and 4 skull electrodes. The auto-spectral characteristics of hippocampal activity and the cross-spectral relationships of the hippocampus with reticular and thalamic structures were utilized to discriminate epochs associated with correct delayed visual matching performance from epochs associated with incorrect performance and nonperformance. An aroused EEG pattern was an apparent prerequisite for correct symbol-matching during the peripheral presentation, but was not a prerequisite for correct response to the initial single stimulus. (M.W.)

119. BERMAN, B. 1967.
Biosatellite Program.
In: B. Berman and D.W. Jenkens, eds. **Space Bioscience. Significant Achievements in Space Science 1966.**
National Aeronautics and Space Administration, NASA SP-155, Washington, D.C. pp. 118-125.

A short history of the development of the biosatellite experiments is given and the contents and objectives of the missions are outlined. Biological experiments flown with the Gemini series are also discussed, notably Gemini III with human leucocytes irradiated in flight; and Gemini VIII and Gemini XII with fertilized frog eggs. Also described are balloon-sounding rocket experiments exposing microorganisms directly to the space environment and collection devices for picking up living microorganisms from space. (R.M.S.)

120. BERRY, L.J. and D.S. SMYTHE. 1962.
Effect of Pure Oxygen at Reduced Pressures on Metabolic Changes in Mice Living Under Simulated Biosatellite Conditions.
School of Aerospace Medicine, SAM-62-24, Brooks Air Force Base, Texas. 11 pages.

One group of mice was maintained on air for 2-3 weeks at simulated altitudes of 14,000 and 20,000 feet, and a second group was kept on pure oxygen at 30,000 and 34,000 feet for a similar period. Subjects were injected subcutaneously with 5 mg cortisone acetate and subsequently fasted for 17 hours in order to determine the "equivalence" between protein catabolized and carbohydrate synthesized. The equivalence was 92, 90, and 98 percent for the control mice and those given pure oxygen at 30,000 and 34,000 feet respectively. In all subjects, there was some variation in the carbohydrate synthesized, but there were no statistical differences in the protein catabolized for mice receiving cortisone. In terms of survival under hypoxic conditions, the rates were 84 to 86 percent for

mice on pure oxygen at 34,000 feet and controls given endotoxin injections, and 35 to 46 percent for those at 14,000 and 20,000 feet altitudes. It appears that low barometric pressure increases urea formation about 50 percent above control levels, but it drops to normal after a sublethal injection of endotoxin. But these animals show an increase in total body NPN equal to the decrease in urinary NPN. The mice tested at simulated altitudes had less increase in excretion of urinary nitrogen after injections of ACTH than did controls. In addition, their adrenal cholesterol was lower than normal, and decreased less following ACTH. (M.W.)

121. CONRAD, H.M. and S.P. JOHNSON. 1968.
The effects of weightlessness on plant growth.
J. Environ. Sci. *11*:17-24.

Along with a general discussion of NASA's Biosatellite Program, the use of pepper plants and wheat seedlings in experiments is described. The experiments are designed to determine the effects of a space environment on plant behavior and growth and to study the response of plants to simulated space flight conditions. (R.M.S.)

122. DURHAM, R.M. et al. 1970.
Reduction of urinary precipitates through manipulation of diet in *Macaca nemestrina*.
Aerospace Med. *41*:259-263.

Pigtail macaques fed a diet of cereal grains consistently produced urine of a high (8.0-9.0) pH, with considerable calcium precipitates present. When the protein and carbohydrate source was changed to casein and sucrose respectively, the urine pH dropped within 24 hours to a point well into the acid range, and insoluble precipitates vanished. Early tests showed that the precipitates, which were primarily calcium phosphates and carbonates, were collecting in and plugging conduits carrying urine from the animal to a waste container. (Authors)

123. EBERHART, J. 1968.
Return of the space monkeys.
Sci. News *94*:93-95.

The rigid medical and psychological procedures for the selection of monkeys for space flights are outlined. The author describes the problems in design of the space capsule and equipment for adequately maintaining and monitoring a monkey passenger. (R.M.S.)

124. EDWARDS, B.F. and S.W. GRAY. 1967.
Experiment preparation for a biosatellite.
Bull. Georgia Acad. Sci. *25*:66.

A totally new method for growing seedlings which permits observation of the shoot and entire root system was developed for this project. The preliminary tests prior to launch have revealed a number of interesting growth effects of the package itself, of vibration simulating flight conditions, and of electromagnetic phenomena. Germination of seeds and growth of seedling organs were inhibited by the electric blanket surrounding each chamber, so that it was found necessary to grow them at lower than optimum temperature. Prelaunch simulated vibrations caused increases in germination and growth. The presence of the other experiments and their supporting apparatus within the capsule raised other problems of possible electromagnetic inhibition. (Authors)

125. EKBERG, D.R. and E.C. SILVER. 1966.
Rapid spectrophotometric method for formaldehyde detection.
Anal. Chem. *38*:1421.

A rapid, accurate procedure has been developed to measure quantitatively the leakage of low aqueous concentrations of formaldehyde, in the presence of ethyl alcohol, across an O-ring seal. A simple modification of the Hehner test for formaldehyde in milk was adapted. Proteose peptone, when added to the sulfuric acid/ferric chloride solution recommended by McLachlan, produces a violet color which adheres to Beer's law in the range of 0 to 3 p.p.m. formaldehyde. (M.W.)

126. EKBERG, D.R. 1967.
Observations of cellular inclusions during vibration.
In: Digest of the Seventh International Conference on Medical and Biological Engineering. Almqvist and Wiksell, Stockholm. p. 504.

Stroboscopic pictures were made of the amoeba (*Pelomyxa carolinensis*) during shaking on a vibration table. The amoeba were flattened between cover slips in such a way that all of the cellular inclusions, except the large food vacuoles, were smaller than the distance between the cover slips. The amoeba were subjected to eight levels of vibration, between 50 and 120 Hz, in order to determine the most damaging frequency. Results are reported as amplitude (Dn) measurement of 1g input. Peak to peak displacement is expressed in microns. The amplitude of the experimental food vacuole appears to be greater than that of the control at 100 Hz. Measurements of small inclusions were found to be difficult at the lower frequencies due to the large amplitudes, which necessitate a low power objective. (R.M.S.)

127. EKBERG, D.R. 1968.
Biosatellite experiments.
J. Brit. Interplan. Soc. *21*:148-153.

Biological experiments selected for the Biosatellite Program were designed to study the effects of weightlessness, ionizing radiation, and other space flight factors on living organisms. Most experiments were chosen so that statistically significant results could be obtained utilizing relatively small packages. The primate flight was chosen because intensive bioinstrumentation permits physiological measurement that could not be performed on a human. Launch, orbital and reentry requirements placed on the spacecraft are presented in tabular form. Preflight tests using prototype hardware were conducted to evaluate the compatibility of experimental organisms and the spacecraft environment. Further tests including simulated flight were made in order to obtain control data. (R.M.S.)

128. ESTRIN, T. et al. 1963.
Facilities in a brain research institute for acquisition, processing and digital computation of neurophysiological data.
In: K. Enslein, ed. Data Acquisition and Processing in Biology and Medicine, Vol. I. Pergamon Press, New York. pp. 191-207.

The facilities of the Data Processing Laboratory of the Brain Research Institute at the University of California at Los Angeles are described. Electrical signals of nervous activity are observed and recorded as part of various studies which: relate electrical activity in single nerve fibers to physicochemical processes; monitor electrical events for mapping purposes; correlate changes in electrical activity with different behavioral and physiological states; classify characteristic patterns for clinical diagnosis; and monitor electrical activity during different stages of sleep and learning. The masses of data resulting from this work are being analyzed by IBM 7090 and IBM 7094 computers. The largest laboratory in the Institute is the Space Biology Laboratory, which has pioneered automatic data collection and computer processing of EEG data during centrifugal acceleration and shaking comparable to booster forces. (M.W.)

129. GAVALAS, R.J. et al. 1970.
Effect of low-level, low-frequency electric fields on EEG and behavior in *Macaca nemestrina*.
Brain Res. *18*:491-501.

A series of experiments has been done to assess the effects of low-level, low-frequency electric fields on the behavior and EEG of monkeys. Three monkeys were implanted with subcortical and cortical EEG electrodes and trained to press a panel on a fixed interval-limited hold schedule. The monkeys were rewarded for pressing the panel once every 5 seconds within a 2.5 second enable period. After the animals were performing well, they were tested under low-level electric fields (2.8 V p-p); the voltage was applied to 2 large metal plates 40 cm apart so that the monkey's head was completely within the field. Fields frequency was set at 7 or 10 c/sec within the range of typical EEG recording (0-33 c/sec). Four hour daily tests of fields-on were randomly interspersed with four hour runs with fields-off. Under the 7 c/sec fields, the monkeys showed a significantly faster interresponse time in 5

of 6 experiments. Mean differences between fields-on and fields-off were 0.4 seconds or greater. The 10 c/sec fields did not produce a reliable effect on behavior. Analysis of the EEG data showed a relative peak in power at the frequency of the fields (10 c/sec and 7 c/sec) for the hippocampus in all 3 monkeys. Similar peaks were seen less consistently in the amygdala and the centre median. (Authors)

130. GORDON, S.A. and E.M. BUESS. 1969.
Radiation-induced chromosome aberrations and rhythms in roots of gravity-compensated *Vicia*.
In: W. Vishniac and F.G. Favorite, eds. **Life Science and Space Research VII.**
North-Holland Publishing Company, Amsterdam. p. 69.

The influence of gravity compensation on radiation-induced chromosome damage was investigated in the secondary roots of broad bean seedlings grown on a clinostat. There was a temporal shift in the frequencies of various aberrations in secondary roots exposed to X-irradiation. Circadian periodicity of mitotic index and nuclear volume were shifted or reversed in phase by compensation; a similar shift was observed in unirradiated, compensated seedlings. In the irradiated cells, a time-dependent increase in numbers of micronuclei was observed. No change in mean DNA content was observed through 2 cell cycles. These observations indicate a probability that periodic phenomena will shift in phase with consequent alteration of type and time-related frequencies of cell aberration in response to single doses of radiation. (R.M.S.)

131. GORMAN, H.A. 1960.
Instrumentation of animals for biosatellite research: Surgical implantation of radio transmitters for determining viability in the mouse.
J. Amer. Vet. Med. Assoc. *137*:693-697.

Mice with radio transmitters implanted have transmitted electrocardiograms, respiration, and muscular activity signals for 27 days. Four mice were used for the first U.S. orbiting biosatellite. The miniature transmitter received its power source from a mercury 400RM dry cell battery and was designed as a small saddle to fit the back of each mouse. Detectors were placed outside each cage, the signals amplified, and retransmitted to Earth. The prospect of applying similar monitoring devices to parameters other than EKG, respiration, and muscular activity is encouraging. Electrocardiography, electroencephalography, electromyography, vectorcardiography, and many other studies are easily within the scope of this type of electronic transmission. (M.W.)

132. GRAY, S.W. and B.F. EDWARDS. 1965.
Effect of Weightlessness and Radiation on the Growth of the Wheat Coleoptile for the Purpose of Defining and Verifying an Experiment Suitable for Use in a Biosatellite.
National Aeronautics and Space Administration, NASA CR-303, Washington, D.C. 64 pages.

Wheat coleoptiles and primary and secondary roots were exposed from 48 to 96 hours to temperatures from 21° to 29°C, X-irradiation up to 40,000r, and centrifugation at 150g. Growth studies showed 25°C to be optimal temperature. Centrifugation and radiation have maximal effect in the induction of anomalous growth at that temperature. At 150g, growth at 21° to 25°C stimulated growth, and sensitivity to radiation was reduced. (R.M.S.)

133. GRAY, S.W. and B.F. EDWARDS. 1965.
Some problems of space biology.
Bull. Georgia Acad. Sci. *23*:49.

Scientific, technical and administrative problems encountered in the construction of prototype hardware for the Biosatellite Program are noted. The technical requirements of living organisms subjected to weightlessness and other space flight factors necessitated the design of new experimental methods for use during orbital flight. (R.M.S.)

134. GRAY, S.W. 1970.
Effects of chronic acceleration on plants.
In: S.A. Gordon and M.J. Cohen, eds. **Gravity and the Organism.**
University of Chicago Press, Chicago. [In Press]

While much work has been done on the response of plants to changes in direction of gravity, there have been few attempts to study their response to changes in the force of gravity by centrifugal acceleration. Growing wheat seedlings have been subjected to chronic acceleration between one and 500 times Earth's gravity. The cross-sectional area of coleoptiles becomes larger and more circular; their resistance to bending increases with the force of acceleration applied. Structural failure of the coleoptile occurs above 500g. Cell diameter increases. Length attained by coleoptile and roots decreases with the force applied, but time required for coleoptile maturation is unchanged. With proper seed selection, germination appears unaffected by accelerative forces up to 300g. Most of the changes we have observed at moderately increased acceleration appear to be adaptive. (Author)

135. GROSCH, D.S. 1967.
The combined effects of irradiation, vibration, and centrifugation on braconid fecundity, fertility and life span.
In: G. Silini, ed. **Radiation Research: Proceedings.**
John Wiley and Sons, New York. p. 99.

Experiments with female *Habrobracon* show antagonistic rather than synergistic interaction of radiation and two kinds of factors postulated to increase stresses in cell structures. However, a preliminary series of experiments revealed that relatively low rates of centrifugation were necessary to avoid displacement of abdominal organs and provide consistent results. Three separate sets of experiments, two reps each, featured 20g for 24 hours during which a total of 750r of gamma rays were delivered from a ^{60}Co source. Egg production for the combined treatment was intermediate between that obtained from centrifugation or irradiation alone. In addition, hatchability was improved over that following radiation alone. Another combination providing egg production and hatchability records exceeding those of radiation alone involved 120 vibrations per second delivered over a four hour period subsequent to 2000r of gamma rays from ^{137}Cs. Furthermore, two 1000r fractions separated by four hours of vibration were not additive in effect. The vibration alone decreases reproductive performance only slightly. Greater efficiency in recovery mechanisms are suggested because improvement is noted particularly in units which were primitive oogonia at the time of treatment. Neither centrifugation alone or in combination with radiation decreased life span significantly. (Author)

136. HAHN, P.M. 1968.
Biosatellite Project.
J. Brit. Interplan. Soc. *21*:136-147.

The primary scientific objectives of the Biosatellite Program are: to determine certain quantitative effects of weightlessness on primates, small animals, plants, and varied microbiological material; to determine the biological effects of the combination of weightlessness and a known source of gamma radiation to determine if there are any synergistic or antagonistic effects or if there are no effects; to determine the effects on the biological rhythms of living organisms when removed from the Earth's rotational influence. This discussion of the Biosatellite Program includes a description of the launch vehicle, the spacecraft and its subsystems, the experiments, and the experiment hardware. (M.W.)

137. HALBERG, F. 1964.
Physiologic rhythms.
In: J.D. Hardy, ed. **Physiological Problems in Space Exploration.**
Charles C. Thomas, Publisher, Springfield, Ill. pp. 299-322.

Research in a space environment can be a valuable method for determining the mechanisms of physiological rhythms. The subjects considered in this paper include: scope, generality and reproducibility of circadian rhythms; deviations from an exact 24-hour period; synchronizers of circadian systems; hormone effects in the light of circadian system analysis; resistance to injury; variance spectra; physiological rhythms and bioastronautics. Problems of physiological rhythms are also pertinent to human engineering for life in an aerospace environment. (L.M.)

138. HALBERG, F. 1964.
Physiological rhythms and bioastronautics.
In: K.E. Schaefer, ed. **Bioastronautics.**
Macmillan Company, New York. pp. 181-195.

The characteristics of rhythms in a terrestrial environment must be reliably defined under specified conditions, and the conditions present during rhythm experiments in space must be delineated as far as possible, so that alterations in rhythm characteristics resulting from exposure to an extraterrestrial environment can be determined. The article discusses: physiological rhythms in man; interactions among rhythms; variance spectra of physiological rhythms; circadian systems; external and internal timing of circadian systems; limits to temporal adaptation; mechanisms of circadian organization; and circadian desynchronization. A number of graphs and tables are presented. (L.A.M.)

139. HALBERG, F. 1965.
Some aspects of biologic data analysis: Longitudinal and transverse profiles of rhythms.
In: J. Aschoff, ed. **Circadian Clocks.**
North-Holland Publishing Company, Amsterdam. pp. 13-22.

It is necessary for concepts of physiologic variation to differentiate between spectral and homeostatic studies, both of which are concerned with the "normal" range of physiologic variation. An evaluation of this range can be made for two complementary reasons. First, in the homeostatic experiment, a "macroscopic" approximation to physiologic function, upper and lower physiologic limits are established so that gross deviations from the "normal" level of a given function can be evaluated. This may be done with regard to clock hour, but in so doing complete information on rhythms is not obtained. A second approach is termed "spectral", and involves a "microscopic" evaluation of physiologic function, with temporal reference standards within the physiologic range utilized. In this case, in order to describe normal and abnormal function, quantities descriptive of rhythms (frequency, amplitude, phase, and "level") are used as end points. The spectral method is predicated on the concept of behavior as rhythmic, with sets of frequency components in many functions. (M.W.)

140. HALBERG, F. et al. 1966.
Reproducibility of circadian temperature rhythm in the rat kept in continuous light of ≈ 30-lux intensity.
The Physiologist *9*:196.

Studies preparatory to a biosatellite survey of circadian and other temperature rhythms are presented. Intraperitoneal temperature, telemetered as a frequency modulated or pulse-code modulated signal from separate groups of mature female rats was recorded at 1-hour intervals for spans of one week or longer. From a least squares spectrum of each individual series, period and amplitude estimates were obtained, averaged for each group, and the standard errors computed. Sprague-Dawley rats, Fisher rats, and DFE rats were subjected to continuous light of various intensities. The estimated period of temperature rhythms from several groups of several stocks kept in LL-30-50 lux was found to differ significantly from the period of the lunar or solar day. (R.M.S.)

141. HALBERG, F. et al. 1967.
Delay of circadian rhythm in rat temperature by phase-shift of lighting regimen is faster than advance.
Fed. Proc. *26*:599.

Intraperitoneal temperature was telemetered at intervals of less than one hour for unrestrained female MSD rats standardized for more than one week on a 24-hour cycle of 12L:12D. The phase of the lighting regimen was then lengthened or shortened by 6 hours in order to observe the effects on the periodicity of the temperature rhythm. Data was analyzed each day by the cosinor method. The phase-shift was faster when the light period was lengthened than when it was shortened. The differences in phase-shifting in physiological cycles, as well as in previously reported activity cycles, are shown to be a function of synchronizer delay or advance. (M.W.)

142. HALBERG, F. 1969.
Chronobiology.
Ann. Rev. Physiol. *31*:675-725.

One purpose of this review is to illustrate developments in the display of objective quantitative estimates of rhythm parameters in terms of their level, amplitude and various phase relations at each

of several frequencies. The information reviewed provides background for unanswered questions in clinical medicine as well as for space flight experiments. Terms are defined and units of rhythmometry are discussed, including criteria to be met in determining end points. The study of rhythms at different levels of complexity, including single frequencies and spectral approaches to components with distinct frequencies, is discussed. Certain statistical methods for analysis of data are illustrated, including imputation of level, amplitude, and acrophase by a least squares fit as a first step in cosinor analysis; cosinor display, and variance spectra. The review shows that the acrophases of certain circadian rhythms in blood, urine, and systemic functions can be objectively determined by electronic computation and that these acrophases agree remarkably well in studies carried out by different investigators working many years and miles apart with differing biophysical, biochemical, or behavioral methodology under dissimilar standardization of the conditions chosen for observation. It is concluded that, as yet, the chronobiologic approach to acquiring new end points from the study of rhythms relates to investigative biology and medicine rather than to clinical practice. (A.R.T.)

143. HALL, L.B. 1966.
The NASA Biosatellite Program.
In: D. Mori, ed. **Proceedings of the International Symposium on Space Technology and Science.** AGNE Publishing, Inc., Tokyo. pp. 791-798.

The various spacecraft systems, types of instrumentation, experiments, and missions of the Biosatellite Program are discussed. The second-generation experiments in this program were developed after the acquisition of several years of baseline data and the design of highly sophisticated equipment. The results of the biosatellite experiments are relevant to a number of major problems in physiology, genetics and evolution. In addition, the data is useful in planning and designing long-term manned space flights such as orbital missions and planetary exploration. Nineteen experiments selected from 187 proposals were to be flown on biosatellites. (M.W.)

144. HANLEY, J. et al. 1968.
Chimpanzee performance: Computer analysis of electroencephalograms.
Nature *220*:879-881.

Electroencephalographic data were recorded from electrodes implanted in the amygdala, hippocampus, frontocentral and temporoparietal cortical areas, midbrain reticular formation, and the nucleus centrum medianum of chimpanzees. Data collected while the animals were playing an electronic version of tic-tac-toe were analyzed on a computer. An attempt was made to correlate EEG patterns along several parameters with behavioral states. The results showed that the parameters selected by computer analysis served to discriminate between two phases of the game and between correct and incorrect decisions. (M.W.)

145. HAUS, E. and F. HALBERG. 1966.
Persisting circadian rhythm in hepatic glycogen of mice during inanition and dehydration.
Experientia *22*:113-114.

Changes in the concentration of liver glycogen were studied in 766 female C mice, housed in three separate rooms under the condition of 12L:12D alternating light and darkness. The mice were standardized on this regimen for seven days with food and water available *ad libitum*. Experimental conditions were altered 16 hours before sampling, as follows: food was removed from one room; food and water were removed from the second room; and a similar disturbance was introduced in the third room even though the food and water were not removed. Glycogen concentration was determined in six samplings from each room, taken at four hour intervals, consisting of approximately 15 mice per sample. Although absolute liver glycogen levels differed in the three groups, the circadian rhythm persisted, and its amplitude during the first day of dehydration and/or starvation compared favorably with that of the controls. The results presented here are of interest to a biosatellite survey of biochemical and other rhythms. (R.M.S.)

146. HETHERINGTON, N.H. et al. 1970.
Prolonged bed rest in healthy human subjects: Summation dial method to analyze nonstationary biological time-series data.
The Physiologist *13*:221.

Previous biorhythm studies have used methods of analyses (harmonic analyses) that assume that the data are stationary in time, i.e., over successive cycles the period, amplitude and phase vary only because of random error. Data produced by 8 healthy male subjects submitted to 56 days of bed rest and maintained on a 14L:10D regimen could not be considered stationary in time as the experiment would be expected to produce changes in amplitude and/or phase. Therefore, it was necessary to resort to other analytical methods. The sole assumption was that the period ($\gamma = 24$ hours) was constant. The data consisted of 6 points per day (on heart rate, body temperature and other parameters) and were fit to the following equation: $Y = m + a \cos wt + b \sin wt$, to produce the estimates, $\hat{a}$ and $\hat{b}$, where the amplitude, $\hat{R} = (\hat{a}^2 + \hat{b}^2)^{1/2}$ and $\text{Tan}^{-1} \hat{\phi} = \hat{b}/\hat{a}$. The point $(\hat{a},\hat{b})$ represents, then, the end of a vector with magnitude $\hat{R}$ and direction $\hat{\phi}$. The summation of these vectors, or train of vectors, produces the summation dial. The direction of the vector train is the hour of the day at which estimated peak activity occurred. Analyses of data by this method indicate that the summation dial is able to detect dynamic changes in time of peak as well as "random walks" (arhythmia); if constancy of period is assumed, a linear change of phase is also detectable. Correlations over time between physiologic parameters may be studied by use of the vector-difference dial which quantifies the angle between the summation dials of the two parameters. (Authors)

147. HOFFMAN, R.A. et al. 1968.
Physiologic and metabolic changes in *Macaca nemestrina* on two types of diets during restraint and nonrestraint: I. Body weight changes, food consumption and urinary excretion of nitrogen, creatine and creatinine.
Aerospace Med. *39*:693-698.

Four groups of male *Macaca nemestrina* ranging in weight from 7.4 to 8.4 kilograms were used in this investigation. The primates were fed two diets which were similar in provision of calories, but which differed in content of major nutrients. Diet A surpassed Diet B in protein, but was exceeded by Diet B in fat, carbohydrate, and major minerals. Calcium was approximately three times as high in the second diet. Two groups of animals were put on the respective diets and were placed in restraint on couches for 35 days followed by 35 days of reconditioning. One group of animals on each diet was nonrestrained throughout the study. All primates, restrained and nonrestrained, were exposed to a biosatellite simulated reentry profile with centrifugation to 12g on the thirty-fifth day of the study. The Diet A restrained primates lost a higher percentage of weight during restraint and exposure to the reentry profile than did the Diet B animals, although the two groups consumed approximately the same quantity of food and the same amount of energy based on initial body weights of the primates. The four groups of animals differed in urinary excretion of nitrogen, creatine, and creatinine. (Authors)

148. HOSHIZAKI, T. et al. 1969.
Central nervous, cardiovascular, and metabolic data of a *Macaca nemestrina* during a 30-day experiment.
In: F.H. Rohles, ed. **Circadian Rhythms in Nonhuman Primates.**
S. Karger, Basel. pp. 8-38.

A discussion of the results of the first full simulation of a 30-day biosatellite flight, which served as a long-duration compatibility test between a *Macaca nemestrina* monkey and the spacecraft, was presented. Data acquisition systems were tested, and initial ground-based data were obtained. The EEG patterns and cardiovascular and metabolic responses of the monkey were studied, as well as body movements, perception, recent memory, and hand-eye coordination. The environment imposed upon the animals had within it a strict 24-hour rhythmicity. The light regime with 12 hours of 6.0 ft-c of light followed by 12 hours of 0.6 ft-c of light was the strongest "Zeitgeber". There were strong diurnal variations in many of the physiological processes of the animals under these conditions. However, in terms of respiratory frequency, the observed 180° phase shift relative to previously reported data in which respiration peaks occurred during the day cannot be explained. Statistically significant differences were found in the EEG pattern between 1:30 a.m. and 1:30 p.m. There was a clear diurnal pattern in most of the parameters measured. (M.W.)

149. JENKINS, D.W. 1965.
The NASA Biosatellite Program.
In: M. Florkin, ed. **Life Sciences and Space Research III.**
North-Holland Publishing Company, Amsterdam. pp. 230-240.

Following exploratory biological experimentation in orbiting spacecraft by Russian and American scientists preparatory to manned space flight, the United States has developed a Biosatellite Program with a second-generation series of critical experiments. Many of these have required several years of baseline study and engineering development. Comprehensive evaluation of effects of dynamic flight factors has been made to permit accurate analysis of the biological effects of unique space environmental factors. Thirty experiments were selected for flight from 185 experiments submitted by the U.S. scientific community to study the effects of weightlessness and decreased gravity at the cellular, tissue, organ, and organism levels. The experiments involve a wide variety of plants and animals from single-celled organisms to higher plants and animals, including primates. Experiments were selected to study the effects of weightlessness combined with a known source of radiation to determine if there are any antagonistic or synergistic genetic or somatic effects on various organisms. Experiments were included to study the effects of the unique environment of the Earth-orbiting satellite and removal from the Earth's rotation in relation to biological rhythms of plants and animals. Pigtail monkeys were instrumented with deep brain probes to study weightlessness effects on the nervous system. A cardiovascular experiment was developed to measure cardiac output using indwelling arterial and venous catheters. Metabolic and calcium loss experiments were also included. Primates and other animals, plants, and microorganisms were exposed in ground tests to simulated dynamic forces of flight profiles including acceleration, spin, and deceleration. (Author)

150. JENKINS, D.W. 1966.
Status report on the biosatellite.
In: S.J. Gerathewohl and D.R. Beem, eds. **Proceedings of the Experimenters' Information Meeting on the Apollo Applications Program in Bioscience.**
National Aeronautics and Space Administration, NASA TM-X-57742, Washington, D.C. pp. 17-19.

Studies done on plants and animals under conditions of decreased gravity environment, radiation in combination with weightlessness, and biorhythmic changes suggest that the vibration and acceleration present during the launch of a space vehicle can result in biological effects. It was necessary, therefore, to obtain data from baseline exposure of all experiments prior to the actual flights. Weightlessness, defined as a free fall produced by the velocity of the spacecraft moving at a speed equal to the Earth's gravitational pull, can be studied during space travel in contrast to zero G effects. The latter cannot be observed because the Sun's or Earth's gravity is always present. (M.W.)

151. KADO, R.T. and W.R. ADEY. 1966.
Electrode problems in central nervous monitoring in performing subjects.
Ann. N.Y. Acad. Sci. *140(Art.1)*:263-278.

The problems of surface and deep EEG electrodes for use in recording performance of man and animals are reviewed. Electrodes were constructed in which metal-to-liquid interface is effected between a tin wire and a solution of stannous chloride, providing low contact potential. The use of special connecting wire ("Mininoise") between the electrodes and amplifying system successfully eliminated electrostatic artifacts. Implantation procedures were developed for reliable recording during acceleration of the whole body in different planes with forces up to 12g and during vibration from 5-40 cps at 2-4g peak to peak. Ten channels of EEG were recorded from surface and deep brain structures during the orbit of a pigtail macaque in the Biosatellite D vehicle. The data was analyzed by computer. (M.W.)

152. KODAMA, A.M. 1970.
Total body water of the pigtailed monkey, *Macaca nemestrina*.
J. Appl. Physiol. *29*:260-262.

The mean body water content of 10 male *Macaca nemestrina* was determined to be 65.5% of body weight using a dilution technique with tritiated water. Tracer substance was injected and samples were drawn from chronically implanted catheters. The mean percent of body fat was computed to be 10.5% and the mean lean body mass to be 89.5% of body weight. (R.M.S.)

153. KOLCUM, E.H. 1963.
Mission growth planned for biosatellite.
Aviat. Week Space Technol. *79*:20-21.

A biosatellite spacecraft system is being designed with the potential for considerable growth beyond the planned 30-day in-orbit lifetime, and the more complex experiments are described here. The system will use a standard satellite shell, with the interior modified for three groups of recoverable experiments: primate, in which a monkey will be the passenger; radiation, using both an on-board source and space radiation; and biorhythm and general biology to test the effects of zero gravity. Missions can be extended by using the vehicle-satellite adapter section to house in-orbit stores. One major modification was the use of a quick-access breech ring to permit installation of biological specimens within 3 hours before launch. Tankage, environmental control, life support, attitude control, and telemetry, tracking and command are also discussed. (M.W.)

154. LINDSLEY, D.B. et al. 1964.
Diurnal activity, behavior and EEG responses in visually deprived monkeys.
Ann. N.Y. Acad. Sci. *117(Art.1)*:564-587.

Infant monkeys reared in darkness and isolation for up to 3 years except for diffuse, unpatterned illumination one hour each day showed 12- to 16-hour activity periods dependent on the schedule of the light stimulation. A bar pressing test showed high and sustained press rates using a one second light as a reward. Sensory hunger was suggested by ceaseless moving, biting and slapping. EEG recordings showed reversed trends in response to light with stimulation tending to produce synchronized waves. This was interpreted as an unspecific sensory system malfunction. The specific sensory system appeared hypersensitive to visual stimulation. (R.M.S.)

155. LINDSLEY, D.F. et al. 1962.
Diurnal activity cycles in monkeys under prolonged visual-pattern deprivation.
J. Comp. Physiol. Psychol. *55*:633-640.

Two macaque monkeys, one rhesus and one cynomolgus, were raised, from 3 weeks of age for 1 year, in an environment isolated from patterned auditory stimulation by white noise and deprived of light except for 1 hour of unpatterned light stimulation each day. The activity of the two monkeys was continuously monitored by a stabilimeter system. Analysis of the records revealed intrinsic diurnal activity cycles which were anchored to the period of light stimulation and shifted position on an absolute time scale when the light-stimulation period was shifted. Dropping of feeding periods or shifting of the feeding schedule had no such effect on the activity cycle. With each shift in the light schedule, a transition period of 3 to 5 weeks was required before the activity cycle stabilized in a new location relative to the light. (Authors)

156. LYON, C.J. and K. YOKOYAMA. 1966.
Orientation of wheat seedling organs in relation to gravity.
Plant Physiol. *41*:1065-1073.

Seedlings of wheat (*Triticum cestivum* L.) were grown in special holders that permitted the coleoptile and early roots to develop in moist air. The orientation of the organs of seedlings erect to gravity was compared with that of organs produced on a horizontal clinostat. Orientation was described by the angular position of each organ tip with reference to the axis of the embryo. Comparative tests were also made with barley, rye, and oat seedlings. The coleoptile of all species developed curvatures in 3 dimensions when geotropic responses were eliminated. The primary root was not precise in its positive geotropism. Seedlings grew on clinostats with much greater variations in the lateral orientation of the central root and with a tendency for it to curve away from the endosperm to a greater degree than in erect seedlings. The symmetry of root system in wheat was found to depend on a specific mechanism. Under the influence of gravity, the earliest lateral roots were oriented in a plane at characteristic angles of about 57.5° with the ideal primary root. The corresponding angles for lateral roots growing on clinostats were greater by about 47.5° as a result of epinasty not previously reported in roots. This force also appeared to be active in the seminal roots of barley and rye but not of oats. The curvatures in coleoptiles grown without the directional effects of gravity correspond to the results of growth imbalance in *Coleus* stems in the absence of lateral transport of their auxin by gravity. Root epinasty appears to be based on auxin imbalance. Curvatures in the primary root are also interpreted as results of asymmetrical distribution of growth hormone. (Authors)

157. LYON, C.J. 1967.
Rotation axes for analysis of gravity effects of plant organs.
Plant Physiol. *42*:875-880.

Epinastic curvatures of branches of *Coleus blumei* Benth. and the growth pattern of wheat (*Triticum aestivum* L.) seedlings on clinostats were used for bioassay of rotation methods for preventing growth responses to gravity. Tumbling a plant end over end was found to be just as effective as rotation about its horizontal axis. The results support the reliability of data from experiments in which an entire plant is rotated about a single horizontal line with only part or none of its immature tissues in horizontal orientation to gravity. (Author)

158. MACK, P.B., R.A. HOFFMAN and A.N. Al-SHAWI. 1968.
Physiologic and metabolic changes in *Macaca nemestrina* on two types of diets during restraint and nonrestraint: II. Bone density changes.
Aerospace Med. *39*:698-704.

Four groups of *Macaca nemestrina* were fed two diets which differed in content of major nutrients, with Diet A higher in protein and Diet B higher in fat, carbohydrate and major minerals. Animals on each diet were held in restraint on couches for 35 days, with exposure to a biosatellite simulated reentry profile involving contrifugation at 12g on the day that the restraint period ended. The period of restraint was followed by 35 days of reconditioning of the formerly restrained animals in cages, with reconditioning of the formerly restrained animals in cages, with the same diets continued. Two groups of unrestrained primates were placed on the respective diets and were kept in cages for 70 days of the experiment except for exposure to the reentry profile on the same day that the restrained primates were exposed. Bone mass was measured periodically in all primates by the method of radiographic bone densitometry, with 17 anatomic sites in the skeletal system evaluated. Bone density was improved significantly in most skeletal sites when the diet containing the higher levels of calcium and phosphorus was the sole experimental factor changed. Restraint had the opposite effect, with loss in skeletal mass found in both dietary groups when this factor was applied. The special diet had a greater effect on improving bone density during the reconditioning period which followed restraint than during the restraint period itself. (Authors)

159. MANGELSON, N.L and A.T.K. COCKETT. 1967.
Long-term antibiotic therapy using silicone rubber as a carrier.
Surg. Forum *18*:531-533.

Subcutaneous implantation of silastic packages containing antibiotics was investigated as a means of prolonged antibacterial administration. Implants of sealed silastic tubing and preformed cakes of room temperature vulcanizing (RTV) silastic were implanted in rhesus monkeys. A viscous mixture of antibiotic, silastic and catalyst was also injected to form rubber in a few minutes. The injection system proved to be the most promising. Significant urinary levels gradually decreasing with time were achieved. Therapeutic levels were observed for 7-10 days with chloramphenicol and nitrofurantoin. (R.M.S.)

160. MANGELSON, N.L., R.T. KADO and A.T.K. COCKETT. 1968.
Silicone rubber uses in the lower urinary tract.
J. Urol. *100*:573-577.

The uses of silicone as implant material are reviewed; a new configuration and implant technique for urinary catheterization is described as used on monkeys. Twelve monkeys were implanted for 28-47 days with no tissue reaction. Each monkey received 2.4 million units of benzathine penicillin G intramuscularly several days after the operation. Urinary concentrations of penicillin ranged between 2.070 units/ml and 0.026 units/ml 5 weeks later, probably accounting for the sterility of urine throughout the testing period. Properties of an ideal soft tissue substitute are discussed; it is said that silicone fulfills these requirements better than any other synthetic material. (R.M.S.)

161. MANGELSON, N.L., R.T. KADO and A.T.K. COCKETT. 1968.
Use of silicone catheters in the lower urinary tract.
Amer. Surg. *34*:170-172.

The authors briefly describe the design and the implantation technique for a silicone urinary catheter. The system allows the maintenance of a closed, sterile system despite the taking of numerous samples. Penicillin G levels in excess of 50 mcg/ml are felt to be effective in preventing urinary infection. (R.M.S.)

162. MANGELSON, N.L. et al. 1968.
Value of closed system urinary drainage combined with penicillin G therapy in preventing urinary tract infections in subhuman primates.
Amer. Surg. *34*:813-816.

The authors described the techniques and apparatus used to successfully maintain indwelling catheters in 11 *Macaca nemestrina* monkeys for 20 to 66 days. A closed system of urinary drainage with careful aseptic technique and administration of penicillin G to maintain levels of 50 or more units/ml in the urine are employed. (R.M.S.)

163. MAYO, A.M. and J.P. NOLAN, Jr. 1964.
Bioengineering and bioinstrumentation.
In: K.E. Schaefer, ed. **Bioastronautics.**
Macmillan Company, New York. pp. 227-273.

Several areas of bioengineering and bioinstrumentation in space vehicle operation are discussed: man-machine integration; integrated control; control station and systems including information and control requirements, sensors, computers, displays, controls, and overall designs; cabin design; atmosphere control system; acceleration and weightlessness; biological research and biosatellites; EKG; EEG; and temperature and blood pressure measurements. Research in the life sciences should proceed at a pace comparable to that of work on integrated man-machine systems to facilitate progress in bioastronautics. It is suggested that a joint effort by life and physical scientists, engineers, and operations scientists would be desirable. (M.W.)

164. MCNEW, J.J. et al. 1968.
Telemetry studies of sleep in the unrestrained chimpanzee.
In: 1968 IEEE National Telemetring Conference Record.
Institute of Electrical and Electronics Engineers, New York. pp. 374-381.

Research is currently in progress on the relative amount of REM sleep in unrestrained chimps in familiar home cage environment as recorded through a four-channel (cortical and subcortical EEG, EOG, EMG) telemetry backpack. The subcortical structures monitored were the right ventral anterior thalamic nucleus, left caudate nucleus, right amygdala, and the right hippocampus. The chimp slept a mean of 11 hours 11 minutes per night, with a mean total time spent in REM of 2 hours 10 minutes. The REM epochs had a duration from 3 to 24 minutes with the mean REM epoch lasting 14 minutes. The EMG amplitude generally did not serve to differentiate the REM stage from other stages of sleep. (M.W.)

165. MEEHAN, J.P. and R.D. RADER. 1967.
Applications of miniature biotelemetry systems to space medicine.
In: Proceedings of National Aerospace Instrumentation Symposium, 1967.
Instrument Society of America, Pittsburgh. pp. 245-250.

A specialized low-power, stable, miniaturized telemetry system, used for recording physiological parameters from unrestrained experimental subjects, is described. The design of such sensing and data-transmission systems and their components is outlined, with emphasis on astrobiomedical applications. (W.F.)

166. MEEHAN, J.P. and J.P. HENRY. 1968.
A program for the study of long-term adaptation to a weightless environment providing three-dimensional freedom of movement.
Space Life Sci. *1*:97-112.

The mechanical details of a working model of a proposed small-animal space station which is currently undergoing bench tests are briefly described together with supporting evidence pointing to the feasibility of the program. The 1/3-m^3 canister weighs less than 250 kg when loaded for a 9-month period. It would transmit by slow-scan television data regarding mice which would be born in the weightless state. Observation of their silhouettes would indicate their growth rates and study of the picture sequence their activity patterns; for example, their use and defense of the feeding and nesting areas and their care of their young. The device would also be used to determine whether the weightless state affected the development of a circadian rhythm or the periodicity of any rhythm that was observed. Recovery of the animals' special living compartment by rendezvous in orbit would permit testing of those born in the device in the Earth's gravity field by familiar methods such as those that have been used for the assessment of negative geotactic responses and for the evaluation of rodents living in vertical, as opposed to horizontal, mazes. (Authors)

167. PACE, N. 1965.
Hemodynamic evaluation of primates before, during and after long periods of weightlessness.
In: L.D. Proctor and R.W. Adey, eds. **Symposium on the Analysis of Central Nervous System and Cardiovascular Data Using Computer Methods.**
National Aeronautics and Space Administration, NASA SP-72, Washington, D.C. pp. 149-163.

Techniques for measuring hemodynamic function before, during, and after long periods of weightlessness in an Earth-orbiting satellite need to be developed. Specifically discussed is progress in automating hemodynamic data collection in a completely unattended primate (explicitly, the pigtailed monkey, *Macaca nemestrina*). Descriptions of the configurations of the experimental environments are given and techniques and instruments used in measuring the vascular parameters are discussed. (M.W.)

168. PARCHER, J.W. 1967.
Use of the Pigtail Monkey, *Macaca Nemestrina*, in Space Bioscience Studies.
National Aeronautics and Space Administration, NASA-TM-X-60822, Washington, D.C. 12 pages.

The purposes of BIOSATELLITE III are discussed. The author indicates a number of physiological indicators that will be measured for use as an estimate of the hazards of extended space flight. The techniques for maintaining a disease-free colony of *Macaca nemestrina*, and the examination of approximately 500 animals to establish baseline values for evaluation of flight data are outlined. Preliminary indications are that physiological parameters are comparable to humans. (R.M.S.)

169. PITTENDRIGH, C.S. 1965.
On the biological problems to be attacked with a series of U.S. satellites in 1966.
In: M. Florkin, ed. **Life Sciences and Space Research III.**
North-Holland Publishing Company, Amsterdam. pp. 206-214.

The following considerations concern the tasks to be undertaken by means of biological satellites: the cardiovascular and neurophysiology of primates, deriving from the need to put man into the weightless state for prolonged durations, and questions concerning the radiation hazard. Many experiments are planned for a single satellite in which it is hoped to discover whether the weightless state significantly affects biological responses to radiation. If, as is expected, there is no synergism between weightlessness and radiation, it will be possible to pursue all other questions about radiation effects in space by experimentation on the ground. Two other classes of questions that satellite experiments may answer having deeper roots in theoretical and cellular physiology are considered. The first of these concerns weightlessness itself. A long list of experiments involving a diversity of material from animal eggs to higher plants will seek to determine whether or not the absence of a gravitational input to the system significantly affects its general performance. Special interest in the U.S. attaches to suggestions from ground-based experiments that normal morphogenesis may fail in plant systems that are exposed to less than about 10^{-5} g. It is also hoped that satellite experiments will help resolve the long-standing debate on the cause of persistent daily rhythmicity in organisms. One school of workers in the U.S. continues to believe that such rhythmicity is caused by organisms sensing an unidentified physical variable with a 24-hour period and hence presumably caused by the Earth's rotation. It is proposed to assay the persistence and

stability of such rhythms on organisms orbiting the Earth with a period of about 90 minutes. Persistence of the rhythm in such orbital conditions would dispose of the theory of external causation; failure of such rhythms to persist would, however, constitute strong though not crucial support in its favor. (Author)

170. PITTS, G.C. et al. 1969.
Rat body composition: Sensor implantation and lighting effects.
Aerospace Med. *40*:417-420.

The effects of transensor-implantation, sham-implantation, or no implantation and three lighting regimens (continuous light, or darkness, or 12 hours of each per day) on body composition of 54 adult female Sprague-Dawley rats were evaluated by analysis of variance with factorial design. Body composition involved chemical fractionation into lipid, water, protein-nitrogen, and ash of eviscerated carcass and viscera treated separately. Statistically significant results included: percent fat in eviscerated carcass reduced in presence of transensor; percent fat in viscera reduced after sham operation; percent water in fat-free viscera increased in presence of the transensor (probably edema evoked by transensor as an irritant); and percent fat in eviscerated carcass increased with daily dark-fraction, probably reflecting effect of lighting regimen on feeding activity. (Authors)

171. POLLARD, E.C. 1965.
Theoretical studies on living systems in the absence of mechanical stress.
J. Theor. Biol. *8*:113-123.

Small single cells should show little effect of weightlessness. Cells as large as 10μ across should show some effect due to redistribution of mitochondria or the nucleolus. It is probable that if there is such a thing as "gravity receptor" in the cell, it is the nucleolus. Systems of cells in which relatively large objects, such as ribosomes, pass from cell to cell should show gravity effects. Quite extensive systems, such as plants which exceed 1 cm in length, should have increased membrane permeability at the lower end. Experiments on weightlessness should also consider temperature as a variable. (Author)

172. PYKE, R.E. et al. 1968.
Physiologic and metabolic changes in *Macaca nemestrina* on two types of diets during restraint and nonrestraint: III. Excretion of calcium and phosphorus.
Aerospace Med. *39*:704-708.

Studies on body weight changes, food consumption, urinary excretion of nitrogen, creatine and creatinine, and bone densitometry as reported in two previous papers of this series have been supplemented by analyses of urinary and fecal excretion of calcium and phosphorus with the results outlined in this report. Although the change to the special diet which provided a higher level of calcium and phosphorus effected an increase in bone density in the majority of the skeletal sites tested, with the imposition of restraint tending to cause a loss in bone density regardless of which diet was fed, urinary calcium excretion did not always follow in a direction opposite from that of the bone density. When the diet change and restraint acted jointly, these antagonistic factors induced no net change in urinary calcium, although the diet change and restraint increased calcium excretion in the feces and phosphorus excretion in both urinary and fecal phosphorus. (Authors)

173. REITE, M.L. et al. 1965.
Normal sleep patterns in macaque monkey.
Arch. Neurol. *12*:133-144.

Normal sleep patterns of *Macaca nemestrina* monkeys were studied in six subjects for 20 nights. Bipolar EEG records were secured from surface and deep electrodes. Eye movements were monitored by EOG and by closed-circuit TV. Clicks were continuously presented at four-second intervals. EEG records were divided into the following stages: awake, drowsy, light, intermediate, deep, and paradoxical. Sleep phases were cyclic, with cycle durations of 75 to 85 minutes, thus resembling human sleep, but the longest segments of deep sleep occurred in the early part of the night. Paradoxical phases occurred during the latter half of the night. Awakening during the night was usually correlated with an initial shift to fast activity in the pontine reticular formation, followed by changes in other deep structures, and lastly, if at all, in cortical areas. (Authors)

174. REYNOLDS, O.E. 1962.
Space biosciences.
AIBS Bull. *12(5)*:49-52.

The author reports on the 1962 space sciences summer study, sponsored by the National Academy of Sciences/Space Science Board, and the early state of NASA's space bioscience programs. The need of exploration of special features of the space environment as unique situations for the study of organism-environment relationships was pointed out. However, two major developments were seen to be necessary before space experiments in biology could attain a high level of success. The first is the development of highly reliable flight systems adapted to the peculiarities of biological experiments, and the second is the close integration of experimental biologists with engineers, physicists, and instrumentation specialists. (R.M.S.)

175. REZNICHEK, R.C. et al. 1968.
Some morphologic and biochemical observations of semen in nemestrina monkeys destined for space flight.
Fertil. Steril. *19*:376-381.

Macaca nemestrina monkeys were electro-ejaculated. Semen obtained was examined morphologically and biochemically. Liquefaction of coagulated semen with trypsin allowed recovery of substantial numbers of sperm. Determination of the percentage of live spermatozoa, the results of which were often at variance with those of the motility studies, would seem to be a useful addition to the standard morphologic examination. Fructose, lactic acid, and citric acid levels were determined. Consistent lower fructose and higher lactic acid values were observed in liquefied coagulum. Although preliminary, the studies provide baseline morphologic and biochemical values of *Macaca nemestrina* semen. Subsequent studies on monkeys before and after space flight may reveal interesting alterations. (Authors)

176. RHODES, J.M. et al. 1965.
Cortical-subcortical relationships of the chimpanzee during different phases of sleep.
In: **Aspects Anatomo-Fonctionnels de la Physiologie du Sommeil.**
Editions du Centre National de la Recherche Scientifique, Paris. pp. 451-473.

The relations between cortical and subcortical systems in different sleep stages using recording leads in the chimpanzee are described. Cross-spectral and other forms of phase analysis techniques were used for data analysis of the EEG recordings. The EEG of the chimp closely resembles that of man, and has been used to define basic sleep patterns. Some of the early stages of sleep were closely examined, i.e., the first three dozing epochs and light sleep. A series of click stimuli was then applied. and evoked responses recorded during the stages between wakefulness and sleep. The results show that the chimpanzee has an EEG like that of man; there is considerable variability in electrical activity during the initial stages of sleep; the hippocampal-neocortical rhythms are not inversely related; and there are several stages of paradoxical sleep, with the rhinencephalon having an especially important role. (M.W.)

177. ROHLES, F.H., Jr. and M.E. GRUNZKE. 1961.
A model for behavioral research with mice in biosatellites.
Aerospace Med. *32*:751-755.

As a model for obtaining behavioral measures with animals in outer space, sustained operant behavior was observed in a mouse that performed on a FR100 reinforcement schedule for 20 minutes out of 6 hours for 96 hours. The performance continued for an additional 96 hours in the absence of reward. It was concluded that this type of performance can be obtained from a mouse for prolonged periods of time and that the behavior is highly reliable and consistent from work period to work period. The study also demonstrates that complete response extinction is slow under this procedure and that meaningful behavioral information can be obtained in the absence of reward. Concerning other disciplines, a 3- or 4-hour cycle used for assessing the behavioral effect of drugs and exposure to unusual environmental conditions, such as prolonged acceleration or vibration, could also be measured with this design. (M.W.)

178. SAUNDERS, J.F., D.W. JENKINS and T.P. DALLOW. 1966.
The NASA Biosatellite Program.
Astro. Aero. *4*:48-52.

An analysis of the mission objectives for biosatellites and an explanation as to why these objectives were selected is presented. The missions can provide data for making precise quantitative analyses, predicting the behavior of organisms in a space environment. The study of weightlessness combined with radiation effects is of special significance. The missions, each using two biosatellites in circular orbits inclined 33° to the equator and at altitudes between 140 and 180 miles, were designed for periods of 3, 21, and 30 days respectively. Included are: experiments on the effects of zero gravity on gravity-dependent organisms, such as frog eggs, and its effects on plant growth; experiments on structural, developmental, and functional patterns; and flights to test the reactions of primates. (W.F.)

179. SCHOENBRUN, R.L. and W.R. ADEY. 1967.
Space flight related stresses on the central nervous system.
Radiat. Res. *Suppl. 7*:423-438.

Recording patterns of brain electrical activity can provide a continuous monitor of the functional integrity of the central nervous system under conditions of space flight related stresses, and in particular will distinguish between normal sleep states and states of unconsciousness induced by hypoxia, circulatory failure, or acceleration effects. In order to identify the distinctions seen in both raw EEG data and spectral analyses, stability measures are used. Stability in time is equivalent to the effective duration of a wave train, and stability in frequency is the effective "spread" in frequency or band width. The product of band width and duration is the "uncertainty relation", and the crossplot of band width vs. duration is the stability of diagram. At least nine different states of EEG activity can be differentiated by this method. Primary attention has been directed toward the brain's limbic system, deep within the temporal lobes. Physical stress such as gravitational forces, centrifuge acceleration, whole-body vibration, and brain irradiation often produce changes in the electrical activity or functional state of this system. (M.W.)

180. SLATER, J.V. et al. 1964.
Heavy ion localization of sensitive embryonic sites in *Tribolium*.
Radiat. Res. *21*:541-549.

The internal localization of organizer sites or the exact locality of areas where embryonic fields occur, enabling members of the cell group to move and grow in concert following a given pattern, can be easily determined by the use of relatively short-range α-particles, where the depth of penetration is regulated with appropriate absorbers. With the Berkeley heavy ion linear accelerator it has been found that two relatively shallow sensitive sites exist in *Tribolium* which regulate wing differentiation and development. Both of these sites appear to have the same intensity and may lie within the membranous wing base areas. As in mice, the developmental interval during which radiation must be applied to give the bulk of the incidence of the malformation is restricted to a very short time interval. A hypothesis has been advanced that the primary intracellular effect of radiation in the embryo is the induction of somatic chromosome aberrations resulting in cell lethal action prior to or during mitosis. Other studies have shown that distal parts of the wing tracheal system are absent in adults previously irradiated as pupae and that cellular breakdown also occurs in these wings. (Authors)

181. SMITH, R.H. and A.R. WHITING. 1966.
X-radiation sensitivity of *Habrobracon* oocytes at diakinesis.
Genetics *54*:364.

This abstract indicates that the diakinesis stage of *Habrobracon* oocytes is as sensitive to radiation doses of 2000 and 2500r as is the first meiotic metaphase. Lethal changes appear in over 99% of eggs so exposed. This was determined by exposing females to the experimental doses of radiation during a phase in the egg-laying cycle when contents of the ovarian sac are known to be 4 oocytes in metaphase I and 1 oocyte in diakinesis. (R.M.S.)

182. STAMBLER, I. 1965.
Bioscience in orbit.
Space/Aeronautics *44*:46-54.

The NASA and USAF programs for biological research in space and some of their implications are discussed. Twenty experiments for biosatellite flights are described. Flights are concerned with: the effects of weightlessness and radiation; responses of rats to weightlessness; and the brain functions and performance of a rhesus monkey under weightlessness. The environmental control system and the USAF in-space biological tests and ground-based research are also described. (M.W.)

183. STUART, J.L. 1969.
Bioengineering in Space: The Biosatellite Urinalysis Instrument.
Jet Propulsion Laboratory, California Institute of Technology, JPL-TR-32-1400, Pasadena. 82 pages.

A urinalysis for calcium, creatinine, and creatine is performed four times daily in a 15-pound automated chemical laboratory. This analysis is performed once daily on standard solutions. The instrument contains a fluorometer for the calcium analyzer, and a nephelometer for the creatine and creatinine analyzer. The instrument also contains the electronics to perform logic sequencing, data acquisition, data storage, the power supplies, and the analyzer amplifiers. All the chemicals required for 150 analyses of each constitutent (a total of 450 analyses) are stored within the instrument, which is designed for a 30-day orbital spacecraft mission. The instrument system and subsystem design configuration, needed to meet the scientific experiment and flight program constraints, are discussed in this report. (Author)

184. TREMOR, J.W. et al. 1965.
Phase difference tests–longitudinal and transverse–on circadian rhythms of C mice.
Fed. Proc. *24*:129.

Blinded and sham-operated male C mice placed on a 12L:12D lighting regimen showed a large phase-difference of their circadian rhythms in motor activity, rectal temperature, blood eosinophils, serum corticosterone and liver glycogen. The average period for these rhythms in blinded mice was approximately 0.5 hours shorter than that of the controls. Rectal temperature rhythms were evaluated transversely by 24-hour profiles taken at weekly intervals for 3 weeks; and other rhythms at the end of the 3 week post-op. period. In addition, gross motor activity rhythms, evaluated longitudinally by capacitance-sensing for over 38 days, were analyzed by temporal amplitude and phase diagrams. Transverse profiles showed typical phase relationships within the circadian systems of both the blinded and sham-operated mice. The phase diagrams showed consistant phase-drifting of a "stable" free-running rhythm in the blinded mice. (M.W.)

185. von BORSTEL, R.C., R.H. SMITH and A.R. WHITING. 1967.
Genetic effects of chronic gamma-radiation on *Habrobracon* sperm.
Radiat. Res. *31*:615.

Because of haploidy of the male, it is possible in *Habrobracon* to test the entire genome for dominant lethality, recessive lethality, inherited partial sterility (the majority being translocations), and visible mutations. In addition, the time of death from the lethal events can be accurately scored during the testing procedure. This genetic system was used to test the effects of chronic ^{85}Sr γ-radiation in comparison with acute X-radiation on *Habrobracon* sperm. The males were exposed to chronic γ-radiation over a 66-hour period. For the acute irradiation studies, in one experiment the males were mated immediately, and in a second, after a 66-hour delay. At the same dose levels the genetic effects did not differ appreciably. Further, a dose-action curve for genetic effects of the chronic γ-radiation over a range from 400 to 4000r shows that 0.5% of the recessive lethals are embryonic and 0.5% are larval or pupal. A linear response for recessive lethals is obtained up to the highest dose given the sperm. At low doses, the inherited partial sterility increases approximately with the square of the dose; above 2000r, the increase is less. (Authors)

186. von BORSTEL, R.C. and R.H. SMITH. 1969.
Differences between genetic responses of *Habrobracon* sperm following protracted and acute gamma irradiation.
Radiat. Res. *39*:462.

It has been reported that genetic responses of *Drosophila* and mouse sperm are equally susceptible to protracted and acute X-radiation. This appears not to be the case for *Habrobracon* sperm. The multi-hit component of dominant lethality is not as pronounced after protracted radiation (66 and 42 hours) as after acute radiation. The dose reduction is approximately 25%. The same holds true for chromosomal translocations as well. On the other hand, the single-hit component of dominant lethality shows little difference, if any, to acute and protracted radiation research. (Authors)

187. WALTER, D.O. and W.R. ADEY. 1966.
Linear and nonlinear mechanisms of brain-wave generation.
Ann. N.Y. Acad. Sci. *128(Art. 3)*:772-780.

EEGs of monkeys stimulated cyclically by whole-body vibration were quantitatively analyzed. Coherence functions relating brain records to the acceleration records and coherent and incoherent peaks at the shaker frequency were plotted. Multivariate spectral analysis is utilized to show the brain's physiological responses to vibration. A comprehensive machine system for spectral analysis by digital filtering is necessary. Records with widely varying intensities and appropriate calculations can be processed without concern for excessive leakage of error buildup. (M.W.)

188. WENDT, R.H. et al. 1963.
Self-maintained visual stimulation in monkeys after long-term visual deprivation.
Science *139*:336-338.

Newborn monkeys reared in darkness for 16 months, except for daily 1-hour periods of exposure to unpatterned light, were allowed to press a lever to obtain unpatterned light. The animals showed apparently insatiable responding, at rates that were extremely high as compared with rates for normally reared control animals. (Authors)

189. WHITING, A.R., R.H. SMITH and R.C. von BORSTEL. 1968.
Methods for radiation studies during oogenesis in *Habrobracon juglandis* (Ashmead).
In: Effects of Radiation on Meiotic Systems.
International Atomic Energy Agency, Vienna. pp. 201-208.

Some of the methods used to study the effect of radiation on the parasitic wasp, *Habrobracon juglandis* (Ashmead), during oogenesis are described. When females are irradiated, clusters of eggs are laid which can be placed in homogeneous categories; those irradiated during the first meiotic metaphase (metaphase I), during diakinesis, and during the earlier first meiotic prophase (diplotene) stage. In most cases the females are bred unmated, so that a criterion of total dominant and recessive lethality is used rather than dominant lethality alone. Recessive lethal mutations, inherited partial sterility, visible mutations, sterility and semisterility, the estimation of genetic parameters, and stage sensitivity are considered. Concerning the latter, metaphase II is 20 times more sensitive than prophase I in terms of dominant and recessive lethality induced by X-radiation. In addition, translocations are rarely formed among chromosomes of irradiated oocytes. (M.W.)

190. WILLOUGHBY, R. 1969.
Toxicity Problems in Plastic Hardware Designed for Biological Space Flight Experiments.
National Aeronautics and Space Administration, NASA TM-X-1818, Washington, D.C. 7 pages.

Testing of plastic hardware for use in space flight experiments involving fertilized frog eggs and sea urchin sperm and unfertilized eggs is described. Acrylic and polycarbonate body materials and flurocarbon elastomer, nitrile, butyl, ethylene-propylene, and 3 silicone types of O-ring materials were tried. Carefully prepared ethylene-propylene and acrylic materials were found to be suitable for frog eggs, but no adequate treatment to render these plastics compatible with sea urchin sperm and eggs was found. (R.M.S.)

191. WINTERS, W.D., R.T. KADO and W.R. ADEY. 1963.
Neurophysiological aspects of space flight.
In: G.W. Morgenthaler and H. Jacobs, eds. **Advances in the Astronautical Sciences. Vol. 10, Manned Lunar Flight.**
American Astronautical Soc., Tarzanna, California. pp. 183-209.

Electroencephalographic (EEG) records have been taken from deep regions of the brains of cats and monkeys with chronically implanted electrodes during centrifugal and shaking accelerations comparable to booster forces. Histological and X-ray controls have indicated that displacement of the electrodes does not occur. A transistorized EEG amplifier suitable for recording in satellite biopack environment has been developed. In centrifuge tests, transverse accelerations up to 10% were associated with rhythmic "arousal" patterns of slow waves in hippocampal regions of the temporal lobe during increasing or decreasing acceleration. Longitudinal accelerations between 5 and 6g produced blackouts after 30 to 40 seconds, with flattening of EEG records, and frequently with induction of epileptic seizure activity in temporal lobe leads. Shaking tests suggest that vibrational acceleration may produce the intermittent "driving" of the cerebral rhythms resembling photic driving, at shaking rates from 11 to 15 c/sec, and from 22 to 30 c/sec. The results of studies simulating a 14-day lunar flight indicate that a fully restrained monkey can survive and perform adequately during this period. The EEG patterns during simulated launch and reentry centrifuge profiles as well as during the period of restraint were not altered. LSD-25 studies reveal that drug-induced seizures occur at lower doses when administered to animals in a relatively sensory-deprived environment. Furthermore, the appearance of this seizure activity may alter the animal's performance. (Authors)

192. WINTERS, W.D. 1963.
Various hormone changes during simulated space stresses in the monkey.
J. Appl. Physiol. *18*:1167-1170.

Experiments were undertaken to study the alteration in urinary excretion of 17-ketogenic steroid, catecholamine, and urine output during several simulated space stresses, i.e., centrifugation, vibration, and isolation with restraint in the monkey. The results indicated a variability of responses depending on the type and degree of stress. Reduction in urine volume was observed in all instances. A fall in steroid and slight elevation in catecholamine excretion was observed following vibration and centrifugation. The centrifugation appeared to be slightly more stressful. Isolation with restraint appears to be a severe stress to the animals as demonstrated by a marked elevation of amine, and a marked reduction in both urine output and steroid excretion. (Author)

193. YOKOYAMA, K., W.H. JONES and T. HOSHIZAKI. 1968.
Rhythm of detached and dissected bean leaf.
Life Sci. 7:705-711.

The bean plant has been used in studies concerned with the effect of space environment on leaf rhythms. Detached leaves were found to display a rhythm approximately the same as that of leaves of intact plants. Petiole-pulvinus-midrib parts dissected from detached leaves show that in the pulvinus area a continuous undulating movement of the extremities is maintained without the rest of the plant and even without the whole leaf blade. This rhythm is thought to be endogenous in nature. (M.W.)

194. YOUNG, R.S. et al. 1970.
Altered gravitational field effects on the fertilized frog egg.
Exp. Cell Res. *59*:267-271.

Xenopus laevis and *Rana pipiens* eggs were centrifuged under various conditions after fertilization. The fertilized egg is most sensitive to altered gravitational fields before first cleavage and abnormalities so induced are typical of the time period of centrifugation. Thus, abnormalities in embryos centrifuged at 40g for 15 minutes during the first 35 minutes after fertilization were confined to a twinning phenomenon. (Authors)

195. ZEMJANIS, R. et al. 1969.
Testicular degeneration in *Macaca nemestrina* monkeys used in pre-space flight tests.
Aerospace Med. *40*:1316-1322.

Testicular tissue was obtained from eight *Macaca nemestrina* monkeys before and after preflight tests. Normal spermatogenesis was observed in all of the pretest specimens, except for one taken from an animal with juvenile testes. One animal which was involved in the test for only seven days had a

normal terminal specimen. Severe testicular degeneration developed in the six remaining animals, all of whom were kept under test conditions for 14 days or more. Seminiferous tubules were generally lined by a single to double layer of Sertoli cells and scattered spermatogonia, mainly type A. Spermatocytes were rare and no spermatozoa were seen. The change involved all of the tubules in a uniform manner. The changes of testicular degeneration in the test animals indicates that potentially adverse effects of space flight conditions on spermatogenesis must be considered. Immobilization appears to be one of the factors deserving particular attention. (Authors)

SECTION III. OTHER BIOLOGICAL FLIGHT EXPERIMENTS

196. ADEY, W.R. and D.D. FLICKINGER. 1965.
Monitoring and prediction of nervous function in space.
In: H. Bjurstedt, ed. **Man in Space.**
Springer-Verlag, New York. pp. 406-424.

Initial results obtained from monitoring human performance during manned orbital flight of 9 hours duration (U.S.) and 96 hours duration (U.S.S.R.) indicate little, if any, demonstrable degradation from the levels achieved during ground-based simulator runs. However, no critical assessment of central nervous system function has been possible during the U.S. missions. Prototype EEG recording equipment to meet the requirements of space flight has been developed to study alertness, judgment, and motor responsiveness during flight. A concomitant series of studies has also been done on animals exposed to the simulated stresses of space flight for up to 14-day periods. These studies have shown that acceleration in the 6-8 g range for 30-60 seconds produced a blackout with seizure-like EEG recordings from the temporal lobe; a "driving" of cerebral rhythms during vibrations of the whole body from 11 to 15 cps; possible mediation of EEG changes through vestibular receptors, with potential involvement of thoraco-abdominal mechanoreceptors; the existence of "paradoxical" sleep with rhythmic discharges of 8 to 10 cps; that during prolonged weightlessness and the major reduction in sensory influx from muscle and joint receptors, relatively normal activation occurs in auditory, visual, and cutaneous receptor mechanisms; and that initial acceleration in a simulated 14-day orbital flight followed by confinement in a capsule was associated with decreased urine and steroid excretion. (M.W.)

197. ADEY, W.R., R.T. KADO and D.O. WALTER. 1966.
Analysis of Baseline and Gemini Flight GT-7 EEG Data with Specification of On-line Computing Requirements.
National Aeronautics and Space Administration, NASA-CR-74716, Washington, D.C. 37 pages.

Spectral analysis by digital computing methods of EEG data from 50 astronaut candidates has shown common characteristics that clearly separate sleep and waking states including concomitants of vigilance and decision-making tasks. Feasibility of on-line computation by a special purpose flight computer for recognition of these states is indicated, and the essential requirements are noted. Application of these techniques to EEG data from the Gemini GT-7 flight is discussed. The detection of shifts in state beyond what is possible by EKG and respiration monitoring is emphasized. (R.M.S.)

198. ADEY, W.R., R.T. KADO and D.O. WALTER. 1967.
Analysis of brain wave records from Gemini flight GT-7 by computations to be used in a thirty day primate flight.
In: A.H. Brown and F.G. Favorite, eds. **Life Sciences and Space Research V.**
North-Holland Publishing Company, Amsterdam. pp. 65-93.

Plans to study central nervous, cardiovascular, and metabolic functions in a macaque monkey (*Macaca nemestrina*) flown in Earth orbit are discussed. Monitoring of central nervous functions will be by electroencephalographic (EEG) electrodes in surface and deep brain structures, and by electromyographic (EMG) recordings from neck and trunk musculature. Eye movements will be recorded by the electro-oculogram (EOG) and galvanic skin responses (GSR) will be assessed from the skin of the foot. Respiration will be recorded with an impedance pneumogram (ZPG), together with the electrocardiogram (EKG). Behavioral tasks will involve tests of perception and recent memory (delayed matching to sample) and eye-hand coordination tests of vestibular functions and spatial orientation. Urine will be collected by a special catheterization technique and subjected to inflight recording. Our extensive development of EEG spectral analysis techniques has proven the feasibility of accurate assessment of states of alertness, particularly in relation to decision-making requirements, and states of drowsiness, fatigue and detection of levels of sleep, including dream states. These techniques have been applied to approximately 60 hours of EEG data gathered on one subject in a Gemini astronaut flight (GT-7). Data will be presented on states of sleep and wakefulness in this subject during the first 55 hours of flight, with reference to possible changes induced by the space environment. (Authors)

199. ADEY, W.R., R.T. KADO and D.O. WALTER. 1967.
Computer analysis of EEG data from Gemini GT-7 flight.
Aerospace Med. *38*:345-359.

A computed analysis, using digital techniques, was performed on closely spaced samples of 55 hours of EEG data from Astronaut Borman, with calculation of auto-spectral and cross-spectral density distributions and coherence functions. Flight data were compared with extensive baseline collections from the same subject in laboratory task performances, in a Gemini flight simulator, and in sleep. Two channels were recorded for the first 29 hours of flight and one thereafter. A detailed analysis of the prelaunch period and first orbit indicated an anticipatory arousal before launch, with changes in power distribution and coherence during the first orbit consistent with strong orienting reactions. Careful assessment of awake flight records throughout the remainder of the 55 hours indicated increased power in the theta band (4 to 7 cps) by comparison with laboratory and flight simulator data. The genesis of this increased theta rhythm in orienting reactions associated with initial exposure to weightlessness is discussed, and the need emphasized for data gathered at later times in longer flights to elucidate persistent shifts from ground-based norms. Sleep analyses from the first two "nights" in space are presented, with clear evidence of minimal sleep on the first night, and four consecutive normal 90-minute cycles on the second night. The sensitivity of EEG records to changing states of alertness and focused attention is reviewed, and the value of the method, in conjunction with adequate computation, for pilot astronaut monitoring is emphasized. (Authors)

200. ADEY, W.R. 1969.
Spectral analysis of EEG data from animals and man during alerting, orienting and discriminative responses.
In: C.R. Evans and T.B. Mulholland, eds. **Attention in Neurophysiology.**
Butterworth, London. pp. 194-229.

A specific application of baselines developed as part of a "normative library" of EEG data is the analysis of 55 hours of EEG material recorded from Frank Borman from the prelaunch period through third day of the Gemini GT-7 flight. Flight data were compared with Borman's own baseline data in the normative library and in simulator tests. Primary interest was in sleep states. During launch and first orbit, theta activity increased over baseline records, with the density increasing to include higher frequencies as the launch became imminent. At one minute before launch, the augmented theta band merged with similarly raised powers in alpha and beta bands. These were correlated with strongly focused attention and orienting responses. At launch, EEG power density was augmented by a factor of 10, in a strong neurophysiological arousal response. During the first half hour of flight, these augmented densities declined slowly, with recurring higher powers in bands about 10 Hz. Coherence between the two EEG channels was high at theta frequencies up to the time of lift-off, and then fell to low values across the entire spectrum for the next 30 minutes. High coherence values were also seen in the second half of the first orbit for about 40 minutes before declining. This frequently follows a challenging experience. Awake records through the rest of the 55 hours showed increased power in the theta band as compared with laboratory and simulator data. Augmented theta activity is seen as a physiological response to the weightless environment, and may arise in augmented orienting responses to an unusual experience. (M.W.)

201. ANONYMOUS. 1966.
Biology. Medicine and physiology.
In: Space Research Direction for the Future.
National Academy of Sciences, National Research Council, Pub. 1403, Washington, D.C. pp. 477-621.

Research findings including medical and behavioral data gained from U.S. and Soviet manned space flights and evidence from aircraft and ground-based work are described. Some of the areas in which additional biomedical information is needed to facilitate progress of the manned program are also discussed. The role of science in space programs such as Gemini, Apollo, Apollo Applications Program, U.S.A.F. Manned Orbiting Laboratory, biosatellites, and ground research is considered with particular importance attached to biomedical studies that can be undertaken in space. The various biosatellite experiments, the requirements and capabilities of manned planetary missions, current knowledge of weightlessness, and the additional work needed on circulation, respiration, metabolism, nutrition, the effect of reduced gravity, radiation, and circadian rhythms are reviewed. (M.W.)

202. BENDER, M.A., P.C. GOOCH and S. KONDO. 1965.
Experiment S-4, zero G and radiation on blood during Gemini III.
In: Manned Space Flight Experiment Symposium, Gemini Missions III and IV.
National Aeronautics and Space Administration, NASA TM-X-56861, Washington, D.C. pp. 217-236.

During the Gemini III manned space flight, studies were done to determine the effects of zero G and radiation on white blood cells. A series of samples of whole human blood was simultaneously irradiated with ^{32}P β-rays during the mission's orbital stage. Chromosome aberration analyses were made for the flight crew, and the single and multiple break aberrations were calculated for the flight and ground control experiments. There was no significant difference between the yields for the multiple break aberrations, but the flight samples were significantly higher in the number of single break aberrations. It is suggested that there is a synergism between radiation and some space flight parameters for the production of human chromosome aberration. The effect is apparently present in the chromosome rejoining system rather than in the breakage itself, inasmuch as it is seen in only single break aberrations. Although a large synergistic effect was not found, the small positive effect was of definite scientific interest. (M.W.)

203. BENDER, M.A., P.C. GOOCH and S. KONDO. 1965.
The Gemini-3 S-4 spaceflight-radiation interaction experiment.
Radiat. Res. *31*:91-111.

To test the suggestion that unusual radiobiological effects are associated with spaceflight, the S-4 experiment was carried out during the Gemini-3 manned spaceflight. The experiment consisted in the irradiation of duplicate series of whole human blood samples simultaneously on the ground and aboard the spacecraft during the orbital phase of the flight. After the mission a cytogenetic analysis was made to determine the frequencies of chromosome aberrations. Comparison of the ground and flight results showed that, although there was no significant difference between the yields of multiple-break aberrations, the yield of single-break aberrations was significantly higher in the flight samples. Several lines of evidence rule out the possibility that this difference was caused by any of the factors already known to influence chromosome aberration production. Preflight and postflight blood samples from the flight crew show that the spaceflight itself did not induce aberrations. A synergism thus appears to exist between radiation and some spaceflight parameter, at least for production of human chromosome aberrations. (Authors)

204. BENDER, M.A., P.C. GOOCH and S. KONDO. 1968.
The Gemini XI S-4 spaceflight-radiation interaction experiment: The human blood experiment.
Radiat. Res. *34*:228-238.

Some of the results of preliminary ground studies and the S-4 blood experiment undertaken during the Gemini XI flight are discussed. The S-4 work was intended to determine whether a radiobiological synergism is present between ionizing radiation and some other parameter associated with spaceflight. Single and multiple break chromosome aberrations were used as biological end points. The results indicated no increase in multiple break aberrations when the cells were irradiated during the flight. In contrast to the Gemini III data, there was no significant increase in the yields of single break aberrations induced by irradiation during the flight. The authors conclude that the significant results found in the Gemini III study probably resulted from a random sampling error and that the hypothesized synergism is not present for either form of human chromosome aberration. (M.W.)

205. COCKETT, A.T.K., C.C. BEEHLER and J.E. ROBERTS. 1962.
Astronautic urolithiasis: A potential hazard during prolonged weightlessness in space travel.
J. Urol. *88*:542-544.

The author discusses urolithiasis as a hazard to space travel. Nine etiologic factors are reviewed for lithiasis. Of these, emphasis is placed on relative immobilization and subsequent muscle inactivity contributing to abnormal metabolism; weightlessness promoting decalcification; decompression and acceleration stresses producing increased sediment; and emotional stress. Vigorous physical exercise, spacecraft rotation, careful diet, proper fluid intake, and careful control of urinary pH are discussed as prophylactic measures. (R.M.S.)

206. COCKETT, A.T.K. and C.C. BEEHLER. 1962.
The protective effects of hypothermia in the exploration of space.
J. Amer. Med. Assoc. *182*:977-979.

This review outlines a significant number of protective effects of general hypothermia. Hypothermia reduces the rate of cellular metabolism. Added advantages of protection from shock in dysbarism, bacteremia, trauma, and excessive G forces are cited. Protection against radiation during hypothermia appears significant. The authors point out that the advantages in terms of reduction in weight and bulk are enormous. However, a state of artificial hibernation appears to be preferable to deeper degrees of cooling, because general body hypothermia is a stressful condition. (Authors)

207. de SERRES, F.J. et al. 1969.
The Gemini-XI S-4 spaceflight-radiation interaction experiment. II. Analysis of survival levels and forward-mutation frequencies in *Neurospora crassa*.
Radiat. Res. *39*:436-444.

The authors report on analysis of an experiment flown aboard Gemini-XI. Samples of *Neurospora crassa* were exposed to different amounts of ^{32}P β-radiation. Flight and ground samples do not differ significantly in survival levels or forward mutation frequencies for specimens irradiated on filters. However, flown samples irradiated in suspension show higher survival and lower forward mutation than ground controls. These results are possibly due to anoxia in the orbited suspension samples. (R.M.S.)

208. de SERRES, F.J. and D.B. SMITH. 1970.
The Gemini-XI S-4 spaceflight-radiation interaction experiment. III. Comparison of the spectra of recessive lethal mutations at specific loci in the *ad-3* region in *Neurospora crassa*.
Radiat. Res. *42*:471-487.

The effects of ^{32}P β-radiation in combination with weightlessness on forward mutation frequencies in the *ad-3* region of *Neurospora crassa* were compared in samples of asexual spores in a two-component heterokaryon, flown aboard Gemini-XI and on the ground. The spectra of genetic alterations was similar in the flight and ground samples irradiated on filters. A specific effect on *ad-3*^{R} was observed on flight samples irradiated in suspension; all classes of point mutation showed the same effect. (R.M.S.)

209. EARLY, L.J. ed. 1966.
Development of a Small Animal Payload and Integration with a Sounding Rocket.
National Aeronautics and Space Administration, NASA-SP-109, Washington, D.C. 98 pages.

The design and performance of a payload vehicle system to be used as a training aid for bioscientists is discussed. Data from six test flights, two of which successfully carried a live animal (200 gram white rat) payload, are presented. The experimental package impacted on water 21.5 minutes after launch. Configuration of the vehicle and performance specifications are discussed in detail using numerous charts, graphs, and photographs to illustrate the text. (R.M.S.)

210. GENERAL ELECTRIC CO. 1968.
Frog Egg Experimental Hardware for Apollo Application Program, Prototype Phase.
National Aeronautics and Space Administration, NASA-CR-73298, Washington, D.C. 55 pages.

This report describes the work effort performed in the design and development of prototype hardware for a frog egg experiment for the Apollo Applications Program. The purpose of the experiment is to determine the effects of zero gravity upon fertilization and germination of frog eggs; therefore, this experiment requires fertilization of the eggs while in orbit under a zero gravity environment. The complete experiment package consists of four modules, each containing three biological units. Each biological unit consists of a series of chambers and valves that enable a complete cycle of growth from fertilization of the frog egg, through germination and preservation at a desired stage of growth. A breadboard unit and a prototype module were designed, fabricated and tested. The feasibility of providing experiment hardware to accomplish the desired function has been successfully

demonstrated where acrylic is utilized for the chambers. Encouraging results have been achieved in using prototype glass chambers; however, breakage problems must be resolved before glass will be acceptable. Reasonable solutions to these problems are available for evaluation. (Author)

211. GERATHEWOHL, S.J. and D.R. BEEM, eds. 1966.
Proceedings of the Experimenters' Information Meeting on the Apollo Applications Program in Bioscience.
National Aeronautics and Space Administration, NASA TM-X-57742, Washington, D.C. 137 pages.

Some of the biological experiments considered for inclusion in the Apollo spacecraft as part of the Apollo Applications Program are reviewed. The bioscience experimentation in Gemini and the Biosatellite Program are reviewed, as well as two experiments that were approved for Apollo. The space environmental factors accessible for study on terrestrial biology are as follows: position above the atmosphere as vantage point for observations; subgravity and weightlessness; ultrahigh vacuum; Van Allen, solar, and cosmic radiations; lack of Earth's magnetic field; escape from terrestrial periodicity; exposure to astrophysical factors; and synergistic effects of space parameters. Experiments suggested for Apollo extended systems were in the areas of genetics, molecular and cellular biology, and morphogenesis and growth. The more sophisticated work to be done in a manned orbiting laboratory is also considered. Gravitational biology is emphasized because it is a unique feature of the space environment; all other parameters can be more or less duplicated on the ground. (M.W.)

212. GREEN, C.D. 1963.
Biomedical capsules.
In: J.H.U. Brown, ed. **Physiology of Man in Space.**
Academic Press, New York. pp. 257-285.

The author describes the design of a number of biomedical capsules for carrying biological payloads into near space and space conditions by balloon and rocket. Control of internal environment, restraining devices, and data collection including telemetry are discussed in a state-of-the-art report. (R.M.S.)

213. GUALTIEROTTI, T. 1963.
Effects of a steady magnetic field on cerebellar centers for equilibrium and orientation.
In: M.W. Makemson and R.M. Baker, Jr., eds. **Twelfth International Astronautical Congress Proceedings, Vol. 2.**
Academic Press, New York. pp. 586-604.

The response of the vestibulo-cerebellar system of the homing pigeon to a steady magnetic field is described. This type of field was used in order to avoid the effects of the induction and production of heat. Observations were made of spontaneous cerebellar activity and cerebellar rotary and post-rotary responses under field conditions. It appears that the magnetic field directly affects living tissue in view of the fact that it is composed of oriented elements characterized by fast activity, e.g., the Purkinje cells of the cerebellum. There is an induced facilitatory effect resulting primarily from a negative change of the potential level of the tissue. It is hypothesized that this may affect the integrative functions of the entire nervous system and that the results support the theory that animal orientation depends on a magnetic vertical Coriolis mechanism for direction finding. (M.W.)

214. GUALTIEROTTI, T. and R. MARGARIA. 1964.
The vestibular function in conditions of zero gravity.
In: M. Florkin and A. Dollfus, eds. **Life Sciences and Space Research II.**
North-Holland Publishing Company, Amsterdam. pp. 317-322.

An experiment is proposed to test labyrinth sensitivity under orbital conditions using either a pigeon or a frog. To test the response of the experimental subject to acceleration, chronic electrodes can be implanted in the vestibular nuclei and in the flocculo-nodular lobe. In this way, vestibular responses from threshold to saturation can be evaluated in terms of the Weber-Fechner law. The apparatus and equipment required for such an experiment in a satellite are described. (M.W.)

215. GUALTIEROTTI, T. and S.J. GERATHEWOHL. 1965.
Spontaneous firing and responses to linear acceleration of single otolith units of the frog during short periods of weightlessness during parabolic flight.
In: The Role of the Vestibular Organs in the Exploration of Space.
National Aeronautics and Space Administration, NASA SP-77, Washington, D.C. pp. 221-229.

By comparing the data from a single vestibular unit producing spontaneous and evoked activity on weightlessness and at 1g, quantitative information can be obtained on the way in which vestibular responses are affected by zero gravity. The method used involves recording from a single nerve fiber over long periods of time, under flight conditions, by means of a tungsten microelectrode. During the flight, the frog is positioned in such a way that the otolith unit is able to respond to acceleration in the direction of the stimulus. The changes seen in the single otolith during parabolic flight were: at the beginning of weightlessness following a high G period, a sudden burst of spontaneous firing; initially, a greater response to acceleration; a rapid suppression of response with restoration to a normal state of 1g; and after several short interval parabolas, a great increase in the overall spontaneous activity of the nerve. It does not seem likely that these effects are due solely to weightlessness or that parabolic flight conditions provide complete information on how weightlessness affects the vestibular organ. (M.W.)

216. GUALTIEROTTI, T. 1966.
Discussion and interpretation of the changes provoked by zero gravity on the otolith unit of frogs.
In: S.J. Gerathewohl and D.R. Beem, eds. **Proceedings of the Experimenters' Information Meeting on the Apollo Applications Program in Bioscience.**
National Aeronautics and Space Administration, NASA-TM-X-57742, Washington, D.C. pp. 31-48.

The biorhythmic responses of otolithic units of live frogs to centrifugal acceleration and parabolic zero gravity flights were studied. Microelectrodes were implanted into the vestibular nerves to record the electrical responses to the experimental conditions. Data were obtained from 400 otolithic units, and showed that most units had different response sensitivities. When the otolithic acceleration responses during level flights were compared with those recorded during parabolic flights, there were higher bioelectric responses for the same unit immediately following the parabolic trials. (M.W.)

217. GUALTIEROTTI, T. and D. ALLTUCKER. 1966.
The relationship between the unit activity of the utriclesaccule of the frog and information transfer.
In: Second Symposium on the Role of the Vestibular Organs in Space Exploration.
National Aeronautics and Space Administration, NASA SP-115, Washington, D.C. pp. 143-149.

The problem discussed is the coding system of the otolith organ in the inner ear. The spontaneous firing and the evoked responses of single otolith units show such a marked irregularity that the mechanism of information transmission cannot be based on instantaneous frequency modulation. Averaging of a single unit discharge requires a long period of time to obtain enough accuracy, whereas the reflex mechanisms of balance act on a split-second basis. Evoked responses from single units bear a logarithmic relation to the stimulus both during transient and steady states. Therefore, a theory of information based on "edges" is not completely satisfactory inasmuch as a graded response is not required. A new theory of information transmission is therefore presented, based on instantaneous averaging of the activity of a number of single otolith units through a time gate similar to that proposed for the auditory pathways. (Authors)

218. GUALTIEROTTI, T. and D.S. ALLTUCKER. 1967.
Prolonged recording from single vestibular units in the frog during plane and space flights—its significance and techniques.
Aerosp. Med. *38*:513-517.

The response of the gravitoceptors of the vestibule to a radical change in the normal 1g gravity environment is described. During high acceleration and vibration, microwave recordings were made from single VIII nerve of frogs. In order to insure survival of two fully instrumented and paralyzed bullfrogs for up to six days while an acceleratory stimulus of fixed parameters was applied to the otolith, a life support system for a space experiment was designed and tested. (M.W.)

219. GUALTIEROTTI, T. and P. BAILEY. 1968.
A neural buoyancy micro-electrode for prolonged recording from single nerve units.
Electroenceph. Clin. Neurophysiol. *25*:77-81.

A new type of electrode which permits continuous recording from single neurons or nerve fibers over long periods of time is reported. This type of electrode also permits recording while the experimental animal is moving or is exposed to high acceleration and vibration. The electrode is designed so that its density is the same as that of the surrounding tissue. In addition, it floats and is counterbalanced against torque momentum in order to avoid standing oscillation. A miniaturized voltage-follower has also been designed for use with the micro-electrode. (M.W.)

220. HOTCHIN, J. et al. 1967.
The Microbiological Flora of the Gemini IX Spacecraft Before and After Flight.
National Aeronautics and Space Administration, NASA-CR-972, Washington, D.C. 16 pages.

Three sites within the Gemini IX space capsule were investigated for microbiological contamination by swabbing before and after the flight. Bacterial or mold growth was observed in three sets of swabs taken before the flight and one set of swabs taken after the flight, and most of the swabs were then found heavily covered with dust. The results were obtained by the completely independent study of the eluted suspensions of the swabs by three research groups and, despite the considerable variation of the detailed results, they show that the inside of the Gemini IX space capsule was contaminated with microbiological materials both before and after the flight. (Authors)

221. HOTCHIN, J. et al. 1967.
The survival of microorganisms in space. Further rocket and balloon borne exposure experiments.
In: A.H. Brown and F.G. Favorite, eds. **Life Sciences and Space Research V.**
North-Holland Publishing Company, Amsterdam. pp. 1-6.

The survival of terrestrial microorganisms (coliphage T_2, *Penicillium roqueforti* mold spores, poliovirus type 1, *Bacillus subtillus* spores) directly exposed to the space environment during two balloon and two rocket flights is reported. The four experiments used 756 exposure units, each about 5 x 5 mm in area, with the organisms deposited by either direct spraying on vinyl coated metal units or by a method of droplet seeding into shallow depressions. The poliovirus showed some rate of survival in all four flight experiments, while the coliphage results were intermediate between the poliovirus and the other microorganisms. (M.W.)

222. HOTCHIN, J. 1968.
Panspermia revisited, or have we already contaminated Mars?
In: P.H.A. Sneath, ed. **Sterilization Techniques for Instruments and Materials as Applied to Space Research.**
COSPAR Secretariat, Paris. pp. 243-254.

The author suggests that although Arrhenius proposed the panspermia concept in order to circumvent spontaneous generation, which was regarded as an impossible occurrence, it is possible that both events can not only occur but may be comparatively frequent. Various studies have shown that microorganisms are markedly inactivated when exposed to solar radiation in space, but this initial high inactivation rate does not persist for more than a few minutes. Some of the results of the following experiments are reviewed: the survival of terrestrial microorganisms in space; microorganisms in terrestrial orbit; accelerative mechanisms for microbial escape; and the probability of achieving microbial escape. (M.W.)

223. HOTCHIN, J., P. LORENZ and C.L. HEMENWAY. 1968.
The survival of terrestrial microorganisms in space at orbital altitudes during Gemini satellite experiments.
In: A.H. Brown and F.G. Favorite, eds. **Life Sciences and Space Research VI.**
North-Holland Publishing Company, Amsterdam. pp. 108-114.

In a study of the survival of terrestrial microorganisms in space aboard the Gemini satellite, the results showed the presence of no living organisms on the Gemini IX or XII sterile collection surfaces

following recovery in which careful handling and extreme precautions were used to prevent contamination of the sterile chamber. During the exposure period, there was no evidence of any living organism having been collected in space. The data of the Gemini flights were analyzed as surviving fractions relative to the shielded flight controls in order to indicate the lethal effect of solar radiation. There was a significant similarity in the survival of the coliphage samples. A small fraction of the population of microorganisms showed extreme resistance. This was probably due to individual differences in susceptibility and to the shielding of a small number of organisms by the aggravated ones, since the radiation flux was fairly constant during the periods of exposure. (M.W.)

224. HOTCHIN, J., F.D. BAKER and L. BENSON. 1969.
Survival of RNA and DNA viruses in space on the Gemini XII satellite.
In: W. Vishniac and F.G. Favorite, eds. **Life Sciences and Space Research VII.**
North-Holland Publishing Company, Amsterdam. pp. 67-68.

The concept that virus particles, which fulfill the size requirements of the panspermia concept, might survive solar radiation propulsion through space if protected by slight UV-opaque shielding was tested. RNA and DNA viruses including tobacco mosaic virus, vaccina, infectious bovine rhinotracheitis, canine hepatitis, PR8 influenza, and T1 *E. coliphage* were flown along with purified lactic dehydrogenase enzyme. A semisolid transparent matrix was developed for support of the viruses; UV screening of this material shown to be comparable to air dried microorganism films. Surviving fractions compared to shielded flown controls after space exposure of approximately 6 hours were *E. coliphage* 0.0004, tobacco mosaic 1.0, rhinotracheitis trace, canine hepatitis 1.0, vaccina 0.2, PR8 1.0, lactic dehydrogenase 0.2. These results indicate that the panspermia hypothesis could hold for viruses. (R.M.S.)

225. KALTER, S.S. et al. 1962.
Stability of viruses on Discoverer flights XXIX and XXX.
Nature *196*:13-14.

The author discusses the virus experiments and the biopacks in which they were carried "piggy-back" on the Discoverer rockets. While these flights were not designed as critical tests of space conditions, they were necessary to ascertain whether or not viruses could be safely orbited and returned to Earth, prior to any attempt to experimentally simulate these conditions. The significance of these experiments is that the viruses, influenza (PR8) and ECHO 1, did withstand the vibration, temperature fluctuations and altered gravitational forces produced by these flight conditions. No significant radiation stresses were encountered. (W.F.)

226. LORENZ, P.R., C.L. HEMENWAY and J. HOTCHIN. 1968.
The biological effectiveness of solar electromagnetic radiation in space.
In: A.H. Brown and F.G. Favorite, eds. **Life Sciences and Space Research VI.**
North-Holland Publishing Company, Amsterdam. pp. 100-107.

An attempt to determine the solar UV action spectrum for dried coliphage T-1 exposed to space under various filters at sounding rocket altitudes between 80 to 150 km. The survival of these microorganisms was compared with the preliminary results of laboratory UV irradiation experiments using monochromatic light sources of wavelengths of 1633, 2062, and 2537 Å and of 3064 to 3200 Å. The results indicate that UV light of wavelengths between 2000 to 3000 Å was mainly responsible for the killing of the filter protected microorganisms. More studies of the biological action spectrum of the vacuum UV light including the Lyman α-emission are needed to determine the cause of the more than 100-fold higher death rate of the microorganisms which were not protected during the space exposure by filters. (Authors)

227. LORENZ, P.R. et al. 1968.
Survival of microorganisms in space.
Sp. Life Sci. *1*:118-130.

Dried suspensions of *Penicillium roqueforti* Thom., coliphage T-1, *Bacillus subtilis*, and tobacco mosaic virus were exposed to space on board the Gemini IX and XII spacecraft and the Gemini VIII target vehicle. All microorganisms tested survived the direct exposure during the Gemini IX

experiment. In the Gemini XII experiment only the T-1 phage survived the direct exposure. The survival was influenced by the suspending medium and depended on the species of the microorganism. After four months of space flight on the Gemini VIII target vehicle, surviving fractions between 2×10^{-3} and 1.0 were found in the unopened flight container. However, microorganisms exposed on the cover of the container during this period were completely inactivated. Shielding against solar ultraviolet radiation during flight resulted in survival of microorganisms exceeding that of the transport controls, and the survival was considered complete. Sterile methylcellulose collection surfaces were exposed to space on board the Gemini IX and XII spacecraft in an attempt to collect viable microorganisms in space. None of the collection surfaces yielded viable microorganisms. (Authors)

228. LORENZ, P.R. et al. 1969.
Viability of microorganisms in space (results of experiments made with rockets and high-altitude balloons).
Kosm. Biol. Med. *3*:28-36.

Penicillium roqueforti spores, T-1 bacteriophage, weakened type 1 poliovirus, and M1 and M4 *Bacillus subtilis* were directly exposed to the environment in dry suspension at altitudes between 35 to 160 km aboard two rockets and two balloons. Two control sets were prepared, one was flown shielded from solar radiation, the other was stored in the laboratory. Survival was dependent upon solar radiation intensity, altitude, type of organism, type of suspension medium, filter used, and initial sowing method. (R.M.S.)

229. MARGARIA. R. and T. GUALTIEROTTI. 1962.
Body susceptibility to high accelerations and to zero gravity condition.
In: T. von Karman, ed. **Advances in Aeronautical Sciences: Proceedings, Vol. 4.**
Pergamon Press, New York. pp. 1081-1103.

Studies concerned with the adverse effects of zero gravity on human performance and well-being are reviewed. Experiments dealing with the surgical destruction of the frog's labyrinths and the subsequent recovery are described. They demonstrate that vision is the most important factor in the frog's ability to compensate for the loss of its vestibular system. Investigations of the otolith system are also mentioned in regard to its sensitivity to acceleration. The authors conclude that: gravity exerts the most significant effect on the labyrinths static organs; external stimulation does not appear to influence the energizer effect on other nervous system structures by the labyrinth and cerebellum; tactile, visual and deep receptor connections function to maintain most of the vestibulo-cerebellar system's sensory inflow; and any adverse effect that gravity may have on the static organ can be easily overcome by a short training period. (M.W.)

230. MARGARIA, R. and T. GUALTIEROTTI. 1963.
The perception of motion, equilibrium and orientation under conditions of zero gravity.
In: **The Man and Technology in the Nuclear Age.**
Associazione Internazionale Uomo nello Spazio, Rome. pp. 493-504.

Few studies have been done on man and animals during the early phases of space exploration, emphasizing the need for additional research on the many fundamental problems in the field. Of particular interest are the effects of weightlessness on the physiology of the organs of the perception of motion, equilibrium, and orientation in space. (M.W.)

231. MARGARIA, R. and T. GUALTIEROTTI. 1965.
Vestibular function in conditions of subgravity.
In: Sixth International and Twelfth European Congress on Aviation and Space Medicine, Vol. 1. Lectures.
Comitato Organizzatore del Congresso di Medicina Aeronautica e Spaziale, Rome. pp. 373-388, pp. 435-436.

The authors discuss the necessity for further study of labyrinth functions and changes under conditions of zero gravity in terms of the problems of space flight. It is suggested that further tests of various theoretical concepts be performed in a satellite with pigeons, monkeys or frogs. (M.W.)

232. MONTGOMERY, P.O'B., Jr. 1966.
Report on approved bioscience experiments for Apollo: Effects of weightlessness on isolated human cells.
In: S.J. Gerathewohl and D.R. Beem, eds. **Proceedings of the Experimenters' Information Meeting on the Apollo Applications Program in Bioscience.**
National Aeronautics and Space Administration, NASA TM-X-57742, Washington, D.C. pp. 21-30.

A biosatellite experimental unit has been developed which can take motion picture photographs of human cell phase-control images in weightlessness for 21 days. The unit consists of time-lapse cameras with locked focuses, chambers for holding cells, microscopes, and media reservoirs which function to feed the cells in accordance with a predetermined schedule. The action of the feed mechanism, rotation of the film, and proper body temperature for the cells are electronically controlled. Another instrument package having two microscopes of different magnification which are to be operated by the astronauts is also described. (M.W.)

233. van der WAL, F.L. and W.D. YOUNG. 1959.
Project MIA (Mouse-in-Able), experiments on physiological response to spaceflight.
Amer. Rocket Soc. J. *29*:716-720.

This report describes one of the early biological experiments flown as a secondary objective in the Able Program. The data collected were extremely limited, but the effects of takeoff and various burning stages on the heart rate of the mice were observed. The telemetered heart rate data is discussed as a comparison to that of the dogs flown in the Russian satellite. No evidence of distress due to weightlessness was observed at this time. (R.M.S.)

234. WALTER, D.O., J.M. RHODES and W.R. ADEY. 1967.
Discriminating among states of consciousness by EEG measurements: A study of four subjects.
Electroenceph. Clin. Neurophysiol. *22*:22-29.

Intensity of activity, mean frequency, equivalent bandwidth, and coherence values in four frequency ranges ("δ, θ, α, β") were calculated for four channels of EEG recorded from each of four normal adult human males, in five experimental situations, including periods of rest and of attention. Stepwise discriminant analysis was applied to the calculated values for all subjects simultaneously to develop formulas for automatic categorization of records into the situation in which they were recorded. After selecting only four parameters, the program correctly categorized 49% of the records; the erroneous categorizations were mainly into related situations. When the records from each subject were separately analyzed, and the four parameters for best discriminating his own records were applied, a higher proportion of records was correctly categorized; the parameters chosen only partially overlapped those chosen for the simultaneous discrimination. Thus an objective method of identifying parameters of the EEG which are important in distinguishing subjects' responses to differing situations has shown its value for developing criteria applicable to many individuals; it has also shown that individuals differ substantially in the list of parameters most distinguishing for their own records. (Authors)

235. WALTER, D.O. et al. 1967.
Electroencephalographic baselines in astronaut candidates estimated by computation and pattern recognition techniques.
Aerospace Med. *38*:371-379.

Methods used in acquisition and analysis of electrophysiological data from 200 astronaut candidates are described. Data from 50 of these subjects have been intensively analyzed in establishment of baselines covering a wide range of states of wakefulness and sleep. Accurately timed physiological stimuli and perceptual and learning tasks were presented to all subjects, thus allowing fine comparison between subjects and establishment of group means for records from each test situation. Spectral analyses were performed by digital methods for each of the 18 scalp EEG channels with leads located according to a modified 10-20 plan. From the primary spectral density parameters, averages and variances were calculated for each scalp location for the whole group of 50 subjects. These averages covered resting conditions, recurrent somatic, auditory and visual stimuli, vigilance tasks, and visual

discriminations at different levels of difficulty. Similar analyses were performed on 30 subjects in drowsy and sleep states. In each case, despite wide individual differences between subjects, the group mean and/or pattern of variance in spectral densities for each test condition presented a characteristic pattern. These patterns were consistent with neurophysiological observations on organization of corticosubcortical interrelations and cerebral systems. Recent evidence relating the scalp EEG to intracellular wave phenomena in cortical neurons is reviewed. In continuing studies, antomated pattern recognition techniques have been applied to the primary outputs of spectral analysis. Preliminary results presented here from 4 subjects indicate an accuracy exceeding 90 percent in computed assignment of states of wakefulness, based on 10 to 20 second epochs of data from 4 EEG channels, and evaluation of 78 variables. Coherence measurements were of great importance in these studies. The value of EEG records in flight monitoring is reviewed and the feasibility of on-line computation discussed. (Authors)

236. YOUNG, R.S. and J.W. TREMOR. 1968.
Weightlessness and the developing frog egg.
In: A.H. Brown and F.G. Favorite, eds. **Life Sciences and Space Research VI.**
North-Holland Publishing Company, Amsterdam. pp. 87-93.

Description of the results of the flight of fertilized frog eggs in the manned orbital flights Gemini VIII and Gemini XII. The experiment was designed to determine the effect of weightlessness or near weightlessness on the ability of the cell to divide normally and on subsequent differentiation and embryogenesis. Eggs were fixed periodically in flight so that recovered material could be carefully compared to simultaneous ground controls in respect to gross morphology and histology. Some embryos were recovered alive after 4 days in orbit. In general, no abnormalities were detected which were inconsistent with the controls. Death, shortly after recovery, of the embryos recovered alive in Gemini XII, remains unexplained. The protocol of the experiment and the experimental hardware are described. (Authors)

SECTION IV. RELATED RESEARCH

237. ADEY, W.R. 1962.
Is there a need for a manned space laboratory?
In: R. Fleisig, E.A. Hine and G.J. Clark, eds. **Lunar Exploration and Spacecraft Systems.** Plenum Press, New York. pp. 170-177.

An excellent biological and animal backup program is needed as a continuing aspect of space studies, including the feasibility of survival and various aspects of brain function under conditions simulating the stresses to which animals are exposed during space flight. Electrodes have been implanted into the brain, and the animal trained to perform a number of different tasks. A variety of records can then be obtained from different deep-brain regions. For example, some areas show fast electrical activity (40 waves/sec) during arousal, the need for food, sexual activity, and aggressive behavior. During discriminative tasks, trains of slow waves occur. The recordings were made in the temporal lobe, which appears to be associated with the emotional state of the animal. During centrifugal acceleration (8-10g), regular slow rhythms appear in some temporal regions. This disappears when acceleration is sustained, but returns with deceleration. (M.W.)

238. CARPENTER, D.L., S.H. FAIRWEATHER and J.E. MORTIMER. 1965.
A longlife biosatellite for exploratory television viewing of physiologic development.
Ann. N.Y. Acad. Sci. *134*:423-439.

The design and instrumentation for a nonrecoverable biosatellite experiment are described. Physiological functions will be monitored by appropriate bioinstrumentation techniques. Gross changes in physical appearance will be displayed by high-resolution TV. In order to accomplish the objectives of the experiment, a rapidly maturing opossum fetus will be used. Neither intraanimal instrumentation involving surgery nor extraanimal instrumentation involving strapping or cementing will be used. (R.M.S.)

239. DANIELS, E.W., J.M. MCNIFF and D.R. EKBERG. 1969.
Nucleopores of the giant amoeba, *Pelomyxa carolinensis.*
Z. Zellforsch. *98*:357-363.

As shown in tangential sections of *Pelomyxa carolinensis* nuclei, there are many pores, each with a surrounding annulus. Each annulus is composed of 8 subannuli or satellites, plus one to three central granules. Each satellite is an electron opaque mass (of much smaller opaque particulates) about 25 nm in diameter. The outer diameter of each annulus is about 115 nm while the inner, or pore diameter, is about 65 nm. The pores occur at distances averaging 185 nm from center to center. Frequently, delicate filaments connect adjacent satellites, and the central granule with the satellites. As seen in cross sections of the nucleus, nucleopores are formed by the fusion of the inner and outer nuclear envelope membranes. The pore appears as a gap, spanned by a delicate diaphragm anchored to the nuclear envelope where its two membranes are fused. Possible functions of the pore-annulus complexes are discussed. (Authors)

240. GRUNBAUM, B.W., J. ZEC and E.L. DURRUM. 1963.
Application of an improved microelectrophoresis technique and immunoelectrophoresis of the serum proteins on cellulose acetate.
Microchem. J. *7*:41-53.

Applications of a recently described adaptation of a microelectrophoresis technique and equipment to use with a cellulose acetate membrane in the study of blood protein fractions are described. The properties of the membrane, properly utilized, allow much better results to be obtained than with filter paper and exhibit technical and practical advantages over gels. The application of the material for rapid immunoelectrophoresis is described. For this purpose, it is markedly superior to gel supports in speed and operational facility. When employed with the technique described, it yields approximately the same degree of definition of immunologically distinguishable factions as that of gel supports. (Authors)

241. GRUNBAUM, B.W. and N. PACE. 1965.
Microchemical urinalysis. I. Simplified determinations of ammonia, urea, creatinine, creatine, phosphate, uric acid, glucose, chloride, calcium, and magnesium.
Microchem. J. *9*:166-183.

Physiological evaluations of environmental stress situations for both humans and animals are determined through profiles of urine constituents. Colorimetric procedures were used to determine ammonia, urea, creatine, creatinine, phosphate, uric acid, and glucose content, while titrimetric measures were used for chloride, calcium, and magnesium. A systematic modification and scaling down of available methods for use with small urine quantities is described. Urinary values for the constituents studied fell in the normal range with the use of microchemical methods. A linear relationship exists for all of the constituents in the colorimetric tests over a wide range of concentrations. Work is currently being done on the microanalysis of the catecholamines and other hormones. (M.W.)

242. GRUNBAUM, B.W. and N. PACE. 1965.
Microchemical urinalysis. II. Microturbidimetric determination of sulfate.
Microchem. J. *9*:184-186.

A microturbidimetric technique with ±2% reproducibility for precipitation of inorganic sulfate from urine with barium in the presence of KCl-HCl buffer and subsequent analysis by colorimetry is described. The method is said to be simple and fast, requiring only strict adherence to procedure due to the empirical nature of the method. (R.M.S.)

243. GRUNBAUM, B.W., N. PACE and M.D. CANNON. 1965.
Microchemical urinalysis. III. A simple automatic recording time-flow titrator.
Microchem. J. *9*:187-192.

A simple automatic titrator for urinalysis is described. The system was developed to facilitate estimation of alkalosis or acidosis brought on by exposure to environmental situations such as high altitude or high CO_2 concentration in humans and animals. This device is suitable for titrating samples as small as 50 μl. It offers a number of desirable qualities for eliminating error and the recording and comparison of data. Titration time is about 2 minutes; accuracy is ±2%. (R.M.S.)

244. GRUNBAUM, B.W. 1965.
A multipurpose micropipette.
Microchem. J. *9*:45-51.

A modified version of a self-adjusting, self-dispensing, all-glass micropipette designed by Grunbaum and Kirk has been developed. The new pipette is a complete unit designed for one-hand operation, and can be easily removed from a specially designed rack which serves as a holder. When not in use, the pipettes are held securely in an immobile position without danger of breakage. The uses of this pipette in microchemical work are described. (M.W.)

245. GRUNBAUM, B.W. 1965.
A self-contained and portable laboratory for microchemical analysis.
Microchem. J. *9*:371-383.

A compact self-contained and mobile laboratory for microanalysis (Cosmolab) was developed. It provides equipment and accessories for the use of simple and reliable microchemical techniques in both the clinical and research laboratories. The Cosmolab can be used in areas where there is inadequate power or water supply. The equipment makes possible the performance of a wide range of analyses in a simplified manner. The equipment does not require that specific methods be used. The analyst may therefore adapt or develop methods to meet his particular needs. The equipment described includes pipettes, spectrocolorimeter, titration system, apparatus for microelectrophoresis, centrifuge, various accessories, power supply, water supply, and the cabinet and work area assembly. The advantages of the Cosmolab are that it is portable, compact, complete, and ready for immediate use anywhere. (Author)

246. GRUNBAUM, B.W. and N. PACE. 1968.
Microchemical urinalysis. IV. Determination of total urinary 17-ketosteroids in the microliter range.
Microchem. J. *13*:396-404.

A procedure is described for the quantitative determination of total 17-ketosteroids in 10-100 μl of urine. The method compares favorably with conventional procedures requiring 5-10 ml of urine. The micromethod has the additional advantage in that it is considerably faster. The extracted steroids appear to be water clear compared to extracts resulting from 5 ml or more of urine. (Authors)

247. GRUNBAUM, B.W. and N. PACE. 1970.
Microchemical urinalysis. V. Quantitative analysis of individual urinary 17-ketosteroids by thin-layer chromatography.
Microchem. J. *15*:103-121.

A procedure is described for the identification and quantitative determination of individual urinary 17-ketosteroids. The method is based on an enzymatic hydrolysis of 1 ml of urine with subsequent extraction in ether and thin-layer chromatography. Pure crystalline 17-ketosteroids were processed as controls to establish the amount of steroid recovered and serve as an identification marker. The limit of sensitivity is estimated to be 0.1 μg of 17-ketosteroid. (Authors)

248. WARD, C.H., S.S. WILKS and H.L. CRAFT. 1970.
Effects of prolonged near weightlessness on growth and gas exchange of photosynthetic plants.
In: C.J. Corum, ed. **Developments in Industrial Microbiology. Vol. 11.**
American Institute of Biological Sciences, Washington, D.C. pp. 276-295.

An experiment was designed to determine the effects of long-duration (30 days) exposure to near weightlessness on growth and gas exchange of the unicellular green alga *Chlorella sorokiniana* and the giant duckweed *Spirodela polyrhiza*. Instrumentation was provided for inflight monitoring of carbon dioxide, oxygen, temperature, and pressure. Transmittance of light through the cultures was measured with photocells to indicate relative growth. Twelve hour light-dark cycles and data acquisition were controlled by programmer. The experiment was launched into near circular east-west orbit at Vandenberg Air Force Base on 30 March 1966 as part of the Air Force Office of Aerospace Research nonrecoverable OV-1 satellite program. Following data reduction, programmed control experiments were performed to simulate conditions, especially temperature, experienced in orbit. The alga experiment developed a gas leak during launch and lost pressure rapidly upon exposure to the vacuum of space. Data from the duckweed experiment were obtained for 230 hours prior to failure of the satellite power system. A nonstatistical comparison of flight and ground control data indicates that photosynthetic and respiratory gas exchange of *Spriodela polyrhiza* was not affected by exposure to near weightlessness for a period of 230 hours. Accuracy of comparison of flight and ground control data was compromised because of inability to quantitatively duplicate the amount of experimental plant material under conditions required for maintenance of axenic culture. (Authors)

SUMMARY

We have already stated that the purpose of this bibliography is to pull together the publications and reports which resulted from research in the Biosatellite Program. However, the real impact of this sort of scientific effort becomes obvious when viewed as a part of the process of determining the direction of future research. The Biosatellite Program has been described as a "pilot program", and as such, must be analyzed along with other experimental efforts, in order to qualitatively and quantitatively evaluate what is known, and to point toward the study of unanticipated biological phenomena. Among the many factors to be considered in the design of future flight experiments is the determination of which of the space flight environmental conditions are most likely to produce unexpected biological effects; and whether or not these conditions can be satisfactorily simulated in ground based laboratories. The state of weightlessness, as encountered during space flight, appears to be one of the conditions under which further biological and biomedical experiments should be conducted.

Information from the literature cited in this bibliography, as well as information from many other sources concerning the study of altered gravity, is summarized and reviewed in the following reference:

SAUNDERS, J.F. 1971.
The biologic effects of altered gravity.
In: S.W. Tromp, ed. **Progress in Human Biometeorology.**
Swits and Zeitlinger, Amsterdam [In Press]

This review presents a comparative discussion, based on results of space flight experiments, of the biologic effects of altered gravity on a variety of life forms and levels of biologic organization. Observations, made during USSR and USA flights, from USSR missions[1] as well as those flown in the United States[2], concerning plants, viruses, microorganisms, invertebrates, amphibians, small mammals, sub-human primates, and man, are presented. The study of altered gravity on Earth, utilizing the centrifuge, clinostat, water immersion, and bed rest to produce various degrees of acceleration, gravity compensation, and immobilization, is discussed in relation to actual flight experiences. Further comparisons are made regarding studies of biochemical substances of physiological significance; of tissue homogenates and cell cultures; and of biologic interaction with weightlessness. The problem of adaptation and, perhaps more important, of readaptation to chronic exposure to orbital flight programs is discussed. The author summarizes that there are persistant obscurities concerning prolonged weightlessness; that data resulting from studies of biologic function or disfunction are often inconclusive; and that adjustment to space environment appears to present fewer problems compared to those of readaptation upon return to the Earth. The comprehensive nature of the review is demonstrated by the 143 references cited. The apparent insight into the challenges confronting this field of research is a result of the author's successful investigative and administrative efforts over the past years. (JEP)

[1] Space Ship 2, 3, 4, 5; Soyuz; Zonds 5, 6, 7; Vostoks 1, 2, 3, 4, 5, 6; Kosmos 110; Voskhod 1 and 2.
[2] OVI-4; Mercury; Gemini; Apollo; Discoverer; Biosatellite II and III; Agena; OFO.

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PERMUTED TITLE INDEX

GENERIC AND COMMON NAMES

Avena sativa	oat seedlings
Bacillus subtilis	typical spore forming bacterium
Capsicum annum	pepper plant
Chlorella sorokiniana	unicellular green alga
Coleus blumei	common coleus plant
Drosophila melanogaster	fruit fly (vinegar gnat)
Escherichia coli	typical intestinal bacterium
Habrobracon juglandis	parasitic wasp
Hordeum vulgare	barley seedlings
Macaca nemestrina	pig-tailed monkey
Neurospora crassa	orange bread mold
Pelomyxa carolinensis	giant multinucleated amoeba
Penicillium roqueforti	penicillin mold
Rana pipiens	common leopard frog
Salmonella typhimurium	common pathogenic bacterium
Secale cereale	rye seedlings
Spirodela polyrhiza	giant duckweed
Tradescantia	spiderwort (blue wild flower)
Tribolium confusum	flour beetle
Triticum aestivum	wheat seedlings
Triticum vulgare	wheat seedlings
Vicia faba	broad bean seedlings

DISTRIBUTION OF LITERATURE

Of the 247 references cited in this bibliography, 135 appeared as articles in scientific journals, 46 as government publications, 38 as contributions in formally published proceedings, and 28 as contributions to other publications, such as books and monographs. This number of journal articles cannot be considered statistically significant in determination of any literature distribution pattern.

The following is an alphabetical list of the 53 journals from which references were cited.

Aerospace Medicine
American Institute of Biological Sciences Bulletin
American Rocket Society Journal
American Surgeon
Analytical Chemistry
Anatomical Record
Annals of the New York Academy of Sciences
Annual Review of Physiology
Archives of Neurology
Astronautics and Aeronautics
Aviation Week & Space Technology

BioScience
Brain Research
Bulletin of the Georgia Academy of Science

Currents in Modern Biology

Drosophila Information Services Research Notes

Electroencephalography and Clinical Neurophysiology
Experientia
Experimental Cell Research
Experimental Neurology

Federation Proceedings
Fertility and Sterility

Genetics

Institute of Radio Engineers Transactions on Bio-medical Electronics

Japanese Journal of Genetics
Journal of the American Medical Association
Journal of the American Veterinary Medical Association
Journal of Applied Physiology
Journal of the British Interplanetary Society
Journal of Comparative and Physiological Psychology
Journal of Environmental Sciences
Journal of Theoretical Biology
Journal of Urology

Kosmicheskaya Biologiya i Meditsina

Life Sciences

Microchemical Journal
Modern Veterinary Practice
Mutation Research

Nature
New Scientist

Physiologist The
Plant Physiology
Proceedings of the National Academy of Sciences

Radiation Botany
Radiation Research

Science
Science News
Space/Aeronautics
Space Life Sciences
Space Science Reviews
Surgical Forum; Clinical Congress of the American College of Surgeons

Yale Scientific Magazine

Zeitschrift fuer Zellorschung und Mikroskopische Anatomie